The SCIENTIFIC FEEDING of CHICKENS

by

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(Revised and Enlarged)

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PREFACE

To the Second Edition

Many noteworthy advances in the science of nutrition have been made since the first edition of this book appeared. The number of known vitamins and vitamers has been increased; additional data on the amino acid content of feedstuffs have been reported; and new information about the functions of some of the mineral elements in nutrition has been obtained. A number of relationships between several of the nutrients have been uncovered. It has been found that there are a number of substances that serve as antagonists to certain nutrients, enzymes, and hormones, and, moreover, that at least some natural feedstuffs contain such antagonists. In general, our knowledge of the roles played by hormones, enzymes, anti-enzymes, bacteria, and drugs in nutrition has been greatly increased.

Some of this new information has direct application to the feeding of chickens, but much of it is, as yet, chiefly of scientific interest and outside the scope of this book. At any rate, the purpose of this edition is essentially the same as that of the first edition, i.e., to bring together, and thus make available, the pertinent information on poultry nutrition. It is hoped that this information will enable anyone to feed chickens scientifically.

Numerous changes have been made in the text and tables, and considerable new material has been added.

Lime Crest Research Laboratory
Newton, New Jersey
September, 1947

PREFACE

To the First Edition

The compilation of the data in this little book was begun in 1936, and as new data became available they were added. Often it was necessary to make extensive changes in the original compilation, especially in the case of the data on the vitamin content of feedstuffs. Many such changes were made during December, 1939, in an effort to bring the compilation up-to-date. Other changes undoubtedly will be necessary as more dependable information is acquired. For this reason the writer will appreciate receiving all new data on the nutritive requirements of chickens and the nutritive properties of feedstuffs. Also, if errors are found in the text or tables the writer wants them called to his attention, because, if this book is to be truly useful, the information it contains must be as accurate and dependable as it is possible to make it.

Poultry Nutrition Laboratory
Beltsville Research Center
Beltsville, Maryland
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THE SCIENTIFIC FEEDING OF CHICKENS

Until recent years the feeding of chickens was an art rather than a science. It was based on systems of rules and methods that were expressions of the experience of those who had been most successful in rearing chickens. Often it was not known why the application of a certain rule or method tended to give good results; but the fact remained that good results were likely to be obtained if the rule or method was followed. However, the scientific study of poultry nutrition has done much to change the situation. Enough knowledge in this field has been accumulated now to place the feeding of chickens on a scientific basis; nevertheless, because much of this knowledge is not readily available to the practical poultryman, the feeding of chickens is still nearly as much an art as it is a science.

The purpose of this book is to bring together, and thus make available, the pertinent information on poultry nutrition that will enable anyone to feed chickens scientifically.

The simplest way, of course, to feed chickens "scientifically" is to use formula feeds made by a reputable manufacturer who has demonstrated that his products are as good as can be made with the aid of the existing knowledge of nutrition. However, a poultryman can derive considerable satisfaction and benefit from having a full knowledge of the nutrient requirements of chickens, the nutritive properties of feedstuffs, and of nutritional diseases.

The satisfaction and benefit that is enjoyed by the poultryman who has a comprehensive knowledge of the

nutrition of the chicken is very much the same as the satisfaction and benefit that is enjoyed by the driver of an automobile who has a comprehensive knowledge of the construction of automobiles. One can be a fairly good driver without having such knowledge, but when something goes wrong, he, in his ignorance, can do considerable damage to his automobile; moreover, he is completely dependent on others in getting his automobile to function properly again. Likewise, one can raise chickens without having a comprehensive knowledge of poultry nutrition; but when the chickens do not grow or lay as well as they should, he incurs a loss and is completely dependent on others in finding out and correcting what is wrong.

NUTRIENTS AND THEIR FUNCTIONS

The feed consumed by chickens normally contains the following seven classes of nutrients: (1) Proteins, (2) carbohydrates, (3) fats, or lipids, (4) minerals, (5) vitamins, (6) extractives, and (7) water. Each class, except the last, includes at least several score, and in some cases thousands, of individual compounds.

Proteins

The proteins are compounds that always contain the chemical elements nitrogen, carbon, hydrogen, oxygen, and sulphur. A number of proteins contain also phosphorus. Hemoglobin, an important protein of the blood, contains a small quantity of iron. Proteins containing copper, iodine, manganese, and zinc have been described.

The most characteristic element in proteins is nitrogen; the quantity is not the same in all proteins, but on the average it accounts for about 16 per cent. This fact is made use of by the chemist in estimating the protein content of feedstuffs. The nitrogen content is first determined by a suitable method and is then multiplied by 6.25, because $100 \div 16 = 6.25$; the result is referred to as "crude protein." This method of estimation obviously does not give the true protein content, because some proteins contains as little as 13.4 per cent of nitgrogen and some contain as much as 19.3 per cent; moreover, all feedstuffs contain variable, small quantities of nitrogen-containing compounds that are not proteins. Notwithstanding, estimates of the "crude protein" content of feedstuffs are of value to the nutritionist.

Although there are many different proteins, all of them are composed chiefly of a relatively small number of comparatively simple compounds known as alpha-amino acids, or more simply as amino acids. As many as 35 or more amino acids have been reported as having been found in proteins; however, the actual presence of only 23 or 24 of them has been verified. Not all the accepted amino acids are in all proteins: some proteins contain a complete or almost complete assortment, but other proteins do not.

In addition to the amino acids, the following compounds are found in certain proteins: Nucleic acids, carbohydrates, hematin, hemocyanin, lecithin, and phosphorus-containing compounds other than nucleic acid or lecithin. Such proteins are referred to as conjugated proteins and include the nucleoproteins, the glucoproteins, the chromoproteins, the lecithoproteins, and the phosphoproteins. The so-called simple proteins, however, are composed only of amino acids.

The accepted amino acids, that is, those the actual presence of which in protein has been verified, include the following:

(1) Alanine
(2) Arginine
(3) Aspartic acid
(4) Cystine
(5) Glutamic acid
(6) Glycine
(7) Histidine
(8) Hydroxyglutamic acid
(9) Hydroxyproline
(10) Iodogorgoic acid
(11) Isoleucine
(12) Leucine
(13) Lysine
(14) Methionine
(15) Norleucine
(16) Phenylalanine
(17) Proline
(18) Serine
(19) Threonine
(20) Thyroxine
(21) Tryptophane
(22) Tyrosine
(23) Valine

All the accepted amino acids are physiologically essential, in the sense that they are needed for normal nutrition. The chicken is able to make in its own body some, but not all, of the amino acids; and those it can-

not make must be present in the feed or else normal nutrition is impossible. The quantity it is able to make of some of the amino acids depends on the quantity of certain other amino acids and other compounds that are present in the diet. For these reasons, the amino acids may be classified as: (1) those that are not required in the diet, (2) those that are required under certain conditions, and (3) those that always are required.

According to the information now available, those amino acids that need not be present in the diet are:

Alanine	Hydroxyproline
Aspartic acid	Serine;

those that are required under certain conditions are:

Cystine	Glycine
Glutamic acid	Proline

Tyrosine;

and those that always are *required,* i.e., must be present in the diet, are:

Arginine	Methionine
Histidine	Phenylalanine
Isoleucine	Threonine
Leucine	Tryptophane
Lysine	Valine.

Cystine is required only when the diet does not contain enough methionine. In other words, methionine can replace all the cystine, but cystine can replace only a portion of the methionine. Homocystine can replace methionine if the diet contains an ample supply of choline. Phenylalanine can replace tryrosine, but tyrosine cannot replace phenylalanine. The chicken is able to synthesize glycine from acetates, and creatine may replace glycine; accordingly, under certain conditions glycine need not be present as such in the diet. Glutamic acid appears to be necessary for maintaining efficient growth, but not for maintaining live weight.

In the practical feeding of chickens two classes of proteins are commonly recognized: (1) plant proteins,

or those derived from plants; and (2) animal proteins, or those derived from animals. Often reference is made to the quality of a protein. A protein is said to be of good quality when it contains a sufficient available quantity of those amino acids that the animal cannot make but which it requires for normal growth and reproduction. In general, the proteins in feedstuffs of plant origin are inferior to those of feedstuffs of animal origin, partly because of their poorer physical availability to the chicken and partly because of their somewhat less satisfactory quantitative distribution of the amino acids required by the chicken.

No two feedstuffs contain the same proteins, and, in general, there are only a few that contain an adequate quantity of all the required amino acids.

The great importance of the proteins in nutrition is indicated by their many functions in the animal organism. They are indispensable constituents of the blood, muscles, organs, skin, tendons, bone, nails, and feathers, in fact, of all animal tissues. They constitute about one-fifth of the weight of the living chicken and between one-eighth and one-seventh of the weight of the whole egg. A secondary function of protein is to serve as a source of energy. When an animal consumes more protein than it requires for growth, reproduction, or the repair of tissue, it may use the excess as a source of energy. Likewise, if feed is withheld from an animal, it is able for a limited period of time to use its own tissues, which are largely protein, as a source of energy.

The amino acids are often referred to as the "building stones" from which the proteins are made. However, several of the amino acids have more or less specific functions. Thyroxine is the hormone that regulates the energy metabolism. In some animals, but not in the chicken, glycine is used for detoxifying benzoic

acid; in the chicken, this function is performed by ornithine. Also, at least in man, glutamic acid is a source of glutamine for the detoxication of phenylacetic acid. Tyrosine and phenylalanine probably are precursors of adrenaline and thyroxine. Tryptophane is a precursor of niacin. Also, it is very likely that creatine, creatinine, purines, certain enzymes and hormones, glutathione, taurine, and other compounds of physiologic importance are derived from amino acids.

Evidence has been obtained which indicates that although a diet is adequate in all the vitamins and mineral elements known to be required by a growing animal, and contains all the required amino acids, it still may not be used efficiently in building the tissues of a growing animal. Certain animal products, e.g., liver, milk, and feces, contain a factor or factors necessary for the efficient use of the diet. Among such factors (or, possibly, names for the same factor) are (1) strepogenin, (2) the so-called "animal protein factor," and (3) a factor found in cow manure and chicken feces. Whether or not these factors are identical or have a similar structure is not known. There is some evidence that one of them, strepogenin, is a polypeptide; and it is not unlikely that all three of them are polypeptides that the animal is unable to synthesize or, at least, is unable to synthesize in sufficient quantity to permit rapid growth. These factors are required in such small quantity that they may be classified as unidentified vitamins.

Carbohydrates

One of the distinguishing characteristics of carbohydrates is that they are composed of carbon, hydrogen, and oxygen, and that the last two elements are present in the same ratio as they are in water. This class of nutrients includes a number of physically un-

like compounds, such as cellulose, starch, dextrin, sugars, pectins, and certain gums. A second characteristic is that when they are digested they are all converted, in whole or in part, into simple sugars.

The more common carbohydrates may be classified as follows:

- Monosaccharides
  - Pentoses (e.g., xylose)
  - Hexoses (e.g., dextrose and levulose)
- Disaccharides (e.g., sucrose and maltose)
- Trisaccharides (e.g., raffinose)
- Polysaccharides
  - The starch group (e.g., starch, glycogen, and dextrin)
  - The cellulose group
    - Cellulose
    - Hemicellulose
      - Pentosans
      - Hexosans
      - Hexo-pentosans
  - Lignin

In the usual proximate chemical analysis of feedstuffs two physically different groups of carbohydrates are determined: (1) crude fiber, and (2) nitrogen-free extract. Crude fiber is the woody, fibrous portion and consists chiefly of cellulose and other polysaccharides. It is of relatively little importance as a nutrient to the chicken because it is not readily digested by that species. Nitrogen-free extract consists of sugars, starch, and hemicelluloses. It includes all the carbohydrates that may be readily digested by animals; but, as chemically determined, it may include, as well, some carbohydrates which are not so readily digested but which may be brought into solution or suspension by dilute solutions of alkalies and acids.

The chief sources of carbohydrates are plant products; most animal products, with the exception of milk and whey, contain only relatively small quantities.

The carbohydrates are the principal source of energy utilized by the animal body. They may be stored in limited quantity, as glycogen, in the liver and muscle tissues. When the quantity of carbohydrates consumed is greater than that which the animal can use to meet its immediate requirement of energy, or store as glycogen, the excess may be converted into fat and be deposited in the body as a future source of energy.

For optimum growth, the chicken appears to require either glucuronic acid or gluconic acid, or certain carbohydrates and carbohydrate derivatives from which the chicken can obtain glucuronic acid.. Among the carbohydrates and carbohydrate derivatives that may be used as sources of glucuronic acid are arabinose, xylose, gum arabic, and chondroitin. Other carbohydrates that play important roles in nutrition are two of the vitamins: ascorbic acid (vitamin C) and inositol.

Fats, or Lipids

The term lipids not only includes the true fats, but also a number of compounds that have physical properties similar to those of the true fats. In this book the term fats will be used to designate the fats and fatlike materials that are found in feedstuffs and animal tissues. In general, the fats contain the same elements as the carbohydrates, namely, carbon, hydrogen, and oxygen, but the ratio of hydrogen to oxygen is greater. Some fats (lipids) contain phosphorus, others contain nitrogen, and still others contain sulphur.

The lipids are generally classified as follows:

Simple lipids

- Fats—chemical combinations of glycerin and fat acids, usually stearic, palmitic, and oleic acids
- Waxes—chemical combinations of fat acids and alcohols other than glycerol

- Compound lipids
  - Phospholipids (e.g., lecithin)
  - Glycolipids
  - Aminolipids
  - Sulpholipids
- Derived lipids
  - Fat acids
  - Sterols—mostly alcohols of high molecular weight.

The lipids are found in all living cells and are important constituents of all animal tissues. They are also found in fat deposits around the internal organs, between the muscles, and under the skin. Complex lipids are present in large quantities in the brain and nerves. In addition to performing important functions in the individual cells, they are carriers of the fat-soluble vitamins.

Certain fat acids—linoleic acid, linolenic acid, and arachidonic acid—are essential for normal nutrition and, like the vitamins, are required in only very small quantities. As a matter of fact, in some of the earlier writings on nutrition these three fat acids were referred to as vitamin F.

One very important function of fats is to serve as a source of energy. For this purpose they are much more efficient than either the proteins or the carbohydrates, inasmuch as a given weight of fat supplies between 2.25 and 2.5 times as much energy as the same weight of either protein or carbohydrate.

The animal may obtain its fat from three sources: the fat, the protein, and the carbohydrates of the feed. In other words, both carbohydrate and protein, after digestion and absorption, may be converted, in part, into fat.

Minerals

The term minerals, as it is now used in animal nutrition, refers simply to the inorganic chemical ele-

ments, i.e. the mineral elements. When a feedstuff is burned, the ash that remains is a mixture of compounds of these mineral elements.

The functions of the mineral elements in the animal body are numerous. Compounds of these elements are found in all tissues. In the absence of certain mineral elements the various organs and tissues of the animal organism are unable to perform their functions.

Calcium, in the form of calcium carbonate, is the chief constituent of eggshells; calcium and phosphorus are characteristic constituents of the bones; iron is an indispensable constituent of the hemoglobin of the blood; iodine is an essential constituent of thyroxine, the hormone secreted by the thyroid gland; compounds of sodium and potassium—together with other mineral elements—are necessary for maintaining the acid-base equilibrium of the body; and chlorine is an important constituent of the secretion of the proventriculus. Calcium also plays an important role in the clotting of blood; minute traces of copper are required by the animal to enable it to utilize iron in the formation of hemoglobin; manganese is essential for reproduction and normal bone development; and cobalt appears to be necessary for the maturing of the red blood cells.

There is good evidence that several of the mineral elements are essential constituents of enzymes or of enzyme systems. For example, copper catalyzes a number of oxidations; iron is a constituent of peroxidase, cytochrome oxidase, and catalase; manganese activates arginase and apparently plays an important role in the synthesis of ascorbic acid; carboxylase contains magnesium; apparently vanadium is required for the enzymic oxidation of phospholipids in the liver; and zinc is a constituent of insulin and carbonic anhydrase.

The chicken requires, for normal nutrition: calcium, phosphorus, potassium, sulphur, sodium, chlorine,

magnesium, iron, copper, manganese, iodine, zinc, silicon, probably cobalt, and possibly fluorine. Many other mineral elements, among which are bromine, aluminum, boron, rubidium, strontium, titanium, vanadium, arsenic, chromium, and lead, have been found in the tissues of chickens and in their eggs, but it has not been demonstrated conclusively whether they are essential constituents or were present only because they had been in the feed that was consumed.

Vitamins

The vitamins are a miscellaneous group of organic compounds that are characterized by the fact that only exceedingly small quantities are required by the animal organism. In spite of the small quantities required, they are absolutely essential for the maintenance of health, growth, and reproduction. Some years ago they were referred to as mysterious compounds of unknown composition, but in recent years the chemical composition and structure of most of them have been determined, and nearly all of them have been made in the chemical laboratory.

The number of both accepted and postulated vitamins is quite large. The accepted vitamins and vitamin-like compounds include:

- Vitamin A and its precursors
  - Vitamin A_2
- Vitamin D
  - Vitamin D_2, or calciferol
  - Vitamin D_3, or activated 7-dehydrocholesterol
  - Also, vitamins D_4, D_5, and D_6
- Vitamin E
  - Alpha-tocopherol
  - Beta-tocopherol
  - Gamma-tocopherol
- Vitamin K
  - Vitamin K_1
  - Vitamin K_2
  - Various chemical compounds of 2-methyl-1, 4-naphthaquinone

Ascorbic acid, or vitamin C
Inositol
Glucuronic acid (replaceable by gluconic acid)
Vitamin P, or citrin
Thiamine, or vitamin B_1
Riboflavin, or vitamin G, or vitamin B_2
Pantothenic acid
Pyridoxine, or vitamin B_6
  Pyridoxal
  Pyridoxamine
Para-aminobenzoic acid
Niacin, or nicotinic acid
  Niacinamide, or nicotinamide
Biotin, or vitamin H
Folic acid (pteroylglutamic acid), or vitamin B_c, or
  lactobacillus casei factor
  Various conjugates of folic acid
Pyracin
  Alpha-pracin or its lactone
  Beta-pyracin or its lactone
Vitamin B_{12}, contains cobalt (*added in proof*)
Choline
Essential fat acids, or vitamin F
  Linoleic acid
  Linolenic acid
  Arachidonic acid

Among the postulated vitamins and vitamin-like factors are:

Gizzard factor, or (anti-)gizzard erosion factor
Strepogenin
Animal protein factor
Cow manure factor (found also in chicken feces)
  (may be vitamin B_{12})
Factor M (probably a complex containing folic acid)
Vitamin B_{10} (possibly a conjugate of folic acid)
Vitamin B_{11} (possibly a conjugate of folic acid)
Anti-stiffness (guinea pig) factor
Grass juice factor
Factor X (*added in proof*)
"Whey" Factor (*added in proof*)

In addition to the above-mentioned postulated vitamins and vitamin-like factors, there have been many others. Most of these have been shown to be mixtures of the accepted vitamins, or to be identical with known vitamins or other chemical compounds. This group includes:

Vitamin B_3
Vitamin B_4
Vitamin B_5
Vitamin B_7
Vitamin B_8, or adenylic acid
Vitamin L_1
Vitamin L_2
Factor R, a conjugate of folic acid
Factor S, possibly strepogenin or "whey" Factor
Factor U
Factor W
Mouse factor
Eluate factor
Cartilage factor, a complex that includes glucuronic acid
SLR (streptococcus lactis R) factor, a member of the folic acid group.

Vitamin A; $C_{19}H_{27}CH_2OH$, an unsaturated cyclic alcohol of high molecular weight; occurs chiefly as fat acid esters in animal tissues. This is one of the so-called fat-soluble vitamins. In addition to vitamin A, itself, there are several carotinoid pigments, notably the carotenes ($C_{40}H_{56}$), that may be converted into vitamin A in the animal body. Compounds that may be transformed by the animal into vitamins are known as vitamin precursors or provitamins. Among the known precursors of vitamin A are: alpha-carotene, beta-carotene, gamma, carotene, cryptoxanthin, echinenone, myxoxanthin, leprotene, aphanin, and aphanicin. The most prevalent of these in feedstuffs is beta-carotene.

The International unit (I. U.) of vitamin A activity is the vitamin A activity of 0.6 microgram of beta-

carotene under certain specified conditions. One I. U. is exactly the same as one U.S.P. unit.

Vitamin A is necessary for growth, reproduction, and the maintenance of health. Also, it is necessary for normal vision. It assists in maintaining the normal structure and functions of epithelial and nerve tissues, and is of value in preventing infections of the eye and respiratory tract. A deficiency of this vitamin or its precursors retards growth, decreases egg production and hatchability, and impairs the general health.

Vitamin A has been found only in materials of animal origin. It is present in egg yolk and in the livers and abdominal fat of normal chickens. Most fish-liver oils, when properly prepared, are rich sources of this vitamin. Especially rich in vitamin A, is the liver oil of certain species of shark. The liver, eyes, and viscera of fresh-water fish contain vitamin A_2, as well as vitamin A.

The precursors of vitamin A occur chiefly in materials of plant origin, but may be found in certain animal products, such as butter and yellow animal fats. There is a small quantity in egg yolk; however, the greater part of the pigments in egg yolk are not provitamins. Green leafly plants, such as kale, grass, alfalfa, and clover, and yellow roots and tubers, such as carrots and sweet potatoes, generally are good sources. When properly prepared, alfalfa meal contains relatively large quantities of carotene, mostly beta-carotene. Yellow corn is a fair source of vitamin A precursors (carotene and cryptoxanthin).

Vitamin A and its precursors are readily destroyed by oxidation. The destruction is accelerated by heat, light, and intimate contact with rancid fat, certain enzymes, and salts of iron and manganese; it is retarded by various antioxidants, both natural and synthetic. Because of the high susceptibility of vitamin A to

oxidation, feeding oils (especially those that are used as a source of vitamin A) should always be stored in closed, well-filled containers and should not be mixed with the feed until a short time before it is to be used. Alfalfa, yellow corn, and other plant products tend to lose as much as 50 percent, or even more, of their vitamin A activity if stored as long as a year; under good conditions of storage, however, the loss may be only 30 percent or somewhat less.

Evidence has accumulated that certain feedstuffs tend to accelerate the destruction of carotene in mixed feeds. Such feedstuffs include meat scrap, tankage, fish meal, and dried milk products. The cause of this destruction of carotene is not known. The destructive power of a given feedstuff appears not to be a fixed property; it varies with the age of the feedstuff and with environmental conditions; some lots of meat scrap or fish meal have it and others appear not to have it.

The comparative stability—or instability—of vitamin A and carotene depends upon a number of things. In the intestines of an animal, vitamin A apparently is more stable than carotene; in mixed feeds, carotene appears to be more stable than vitamin A. In either case, the stability of vitamin A and carotene is increased by the presence of one or more of the tocopherols or other anti-oxidants. For this reason, more vitamin A is stored by an animal on a diet adequate in vitamin E than by an animal on a diet deficient in vitamin E, when the vitamin A content of the two diets is the same. Because vitamin E is able to increase the storage of vitamin A in the liver under certain conditions, it has been concluded that vitamin E has a sparing action for vitamin A. The evidence now available suggests that vitamin E merely protects vitamin A from destruction and that it does not spare vitamin A

in the sense that it can replace it in part or reduce the animal's actual requirement for it.

Vitamin D; D_2, or calciferol, $C_{28}H_{43}OH$; D_3, or activated 7-dehydrocholesterol, $C_{27}H_{43}OH$; the latter of these two occurs only in the animal organism. This vitamin is classified as a fat-soluble vitamin. It occurs in several forms, including the two referred to immediately above. Some of these forms are more effective than others in the chicken. Vitamin D is unique among the vitamins, in that it may be produced in the skin of animals (comb, wattles, and shanks of chickens) through the action of ultraviolet rays, which may be obtained from the sun or from artificial sources, such as the carbon arc or the quartz-enclosed mercury-vapor lamp.

There are a number of provitamins D. They occur in both plant and animal materials. They are not converted into vitamin D by the animal, itself, as the precursors of vitamin A are converted into vitamin A. They must be acted on by an outside agency, such as light, various rays (including x-rays) and emanations, and high frequency alternating current.

Vitamin D is necessary for normal growth (especially the growth of the skeleton), egg production, and hatchability. A deficiency of vitamin D produces rickets in growing chicks and decreases the egg production of laying hens and lowers the hatchability of their eggs. On the other hand, if a chicken gets too much vitamin D, 5 or more times the quantity normally supplied, egg production and hatchability tend to decrease; and if the excess of vitamin D is very large, there also may be a deposition of calcium in various tissues of the body other than the bones.

Vitamin D is not widely distributed in nature. Certain fish oils are the richest sources. Egg yolk is a fair source. The ordinary feedstuffs, particularly those

classed as concentrates (e.g., the grains and other seeds and their byproducts), contain extremely little or none. The small quantity of vitamin D found in some hays is not very effective in the chicken. However, vitamin D activity may be conferred on certain oils and feedstuffs by irradiation with ultraviolet rays.

Vitamin D is comparatively stable under ordinary conditions; however, there is some destruction of this vitamin in feeds containing feeding oil, when the feeds are stored for a long time. When vitamin D, especially if it is dissolved in oil, comes in intimate contact with mineral compounds or products, such as sulphur, oystershell flour, steamed bone meal, salt, ground limestone, and sand, or with certain feedstuffs, such as dried whey, dried skim milk, and sugar, its destruction is greatly accelerated. For these reasons, a concentrated source of vitamin D should not be pre-mixed with any of the mineral ingredients of a feed mixture; preferably, it should be pre-mixed with ground corn, bran, middlings, alfalfa meal, or soybean meal.

Inasmuch as some forms of vitamin D (e.g., vitamin D_3) are more effective than others in the chicken, all sources of this vitamin intended for use in the feeding of chickens should be purchased on the basis of their content of A.O.A.C. chick units of vitamin D.

Vitamin E; alpha-tocopherol, $C_{29}H_{50}O_2$; also, the less active beta-tocopherol and gamma-tocopherol, $C_{28}H_{48}O_2$; occurs predominantly in plant materials, but is found also in small quantities in certain animal products, such as eggs, milk, and fresh meat. This is another of the fat-soluble vitamins. It is rather widely distributed in nature; green leaves and the germs of seeds are the best known sources; it is also found in certain fresh fats.

Vitamin E is necessary for reproduction and the hatchability of eggs. A marked and prolonged defi-

ciency of this vitamin in the male chicken causes degeneration of the testes. In the young growing chicken, a deficiency of vitamin E causes a condition known as nutritional encephalomalacia; and, depending on the type of diet that is fed, may cause an alimentary exudative diathesis followed by increased permeability of the capillaries and dystrophy of the muscles.

Vitamin E. is quite stable under ordinary conditions, but is very readily and quickly destroyed by rancid fats. For this reason, rancid feeds—even when the rancidity is slight—should not be fed to chickens.

Vitamin K; K_1, or phylloquinone, 2-methyl-3-phytyl-1,4-naphthaquinone, $C_{31}H_{46}O_2$; K_2, 2-methyl-3-difarnesyl-1,4-naphthaquinone, $C_{41}H_{56}O_2$; occurs chiefly in plant materials and microgranisms, but small quantities have been found in hog liver, milk, and eggs. This is another of the so-called fat-soluble vitamins; however, water-soluble derivatives of 2-methyl-1,4-naphthaquinone that have vitamin K activity have been prepared.

This vitamin is known also as the anti-hemorrhagic factor, because in vitamin K deficiency the prothrombin content of the blood is markedly decreased and the clotting time is greatly increased. A deficiency of vitamin K in the diet of the very young chick results in massive hemorrhages, which may appear almost anywhere on the body and especially on the wings and legs.

Vitamin K is relatively stable at ordinary temperatures, but is destroyed by alkalies and by exposure to light.

Ascorbic acid, or vitamin C; the lactone of 2-keto-1-gulonic acid (2, 3 dienol-1-gulonic acid lactone), $C_6H_8O_6$; occurs in virtually all plant and animal tissues. This is one of the water-soluble vitamins. The chicken normally is able to make its own vitamin C, and for that reason it generally is believed that the diet of this

species need not contain any. Instances have been observed, however, in which the addition of ascorbic acid to certain types of diets has seemed to give a small stimulation to the growth of young chicks. Moreover, it may be pointed out that there are certain conditions (e.g., pullorum disease) in which ascorbic acid may be destroyed more rapidly than it can be synthesized. This strongly suggests that it is advisable to include some alfalfa meal or fresh green feed in the diet of growing chicks.

Inositol; hexahydroxy cyclohexane, $C_6H_{12}O_6$; occurs in nearly all plant and animal tissues. This is a water-soluble vitamin. It is found not only in the egg (largely in combined form), but also in the newly hatched chick. Whether or not either the growing chick or the adult chicken requires pre-formed inositol for normal nutrition is not known. Undoubtedly, however, the chicken requires inositol, regardless of whether it is able to synthesize it or not. In any case, instances have been reported in which the addition of inositol to purified diets resulted in an increased rate of growth. In view of the fact that inositol is present in virtually all feedstuffs, it is unlikely that practical feed mixtures are deficient in this factor.

It is of more than passing interest that the addition of inositol to a diet deficient in vitamin E has been reported to prevent the development of encephalomalacia and exudative diathesis in the chick.

Glucuronic acid (also spelled glycuronic acid); one of the uronic acids; $C_6H_{10}O_7$; is present in virtually all feedstuffs. This factor appears to be necessary for the growth of chickens. It is unlikely that practical diets for chickens are deficient in this factor; this is especially true in view of the fact that gluconic acid can replace it, and several carbohydrates and carbohydrate derivatives may serve as sources of it.

Vitamin P, or citrin; a crude mixture of the glucosides of eriodictin and hesperidin; it is present in the tissues and juices of many plants. In some species of animals, a deficiency of vitamin P increases capillary fragility and permeability. It is not known whether or not it is required by the chicken.

Thiamine, or vitamin B_1; $C_{12}H_{17}N_4OSCl$; a thiazol-pyrimidine compound; occurs widely in nature, both as the free compound and in the form of several complexes. This is one of the water-soluble vitamins.

Thiamine is necessary for growth, the maintenance of appetite and a normal condition of the intestinal tract, and for the prevention of polyneuritis, which is primarily a nerve toxicosis that results from the incomplete metabolism of pyruvic acid. It plays an important part in the utilization of carbohydrates by the animal organism; in particular, thiamine, in the form of its pyrophosphate (cocarboxylase), catalyzes both the carboxylation and decarboxylation of pyruvic acid, an intermediate product of carbohydrate metabolism.

Nearly all plant and animal tissues contain thiamine. Yeast, the germs of seeds, and the seeds of legumes are among the richer sources. In general, the seeds are all good sources. The green vegetables are fairly good sources. It is found in eggs, milk, and meat; however, animals do not store large quantities. In typical diets for chickens the chief sources of this vitamin are the cereal grains and their byproducts; accordingly, there is little likelihood of encountering a deficiency of thiamine in chickens that are fed typical diets.

Thiamine is comparatively stable to heat when dry, but is readily destroyed in the presence of moisture, especially in the presence of alkalies. It is quite easily and quickly destroyed by sulfites. Under ordinary conditions, feedstuffs may be stored for a long time without there being any serious loss of this vitamin.

Riboflavin, or vitamin G, or vitamin B_2; 6,7-dimethyl-9-d-ribitylisoalloxazine, $C_{17}H_{20}N_4O_6$; occurs widely in nature, both in the free form and in combination with phosphoric acid or phosphoric acid and protein. It is sometimes classed as a water-soluble vitamin, but it is only very slightly soluble in water.

Riboflavin is necessary for growth, the normal functioning of the nervous system (especially the main peripheral nerve trunks), and for the metabolism of carbohydrate, fat, and protein. It is necessary for egg production, the development of the embryo, and the hatchability of eggs. It is an essential component of a number of co-enzymes and enzyme systems, and, as such, performs a function in catalyzing the oxidation processes of the cell.

All plant and animal tissues contain riboflavin; in fact it is highly probable that all plant and animal cells contain some. Among the richer sources are: liver and other glandular tissues, yeast and many fermentation byproducts, and dried milk and milk byproducts, such as dried whey, dried buttermilk, and dried skim milk. Alfalfa, if properly harvested, is a very good source. Fish meals, meat scrap, and wheat germ are fair sources. The ceral grains contain relatively little. Many feed mixtures for poultry contain less riboflavin than is desirable, unless a special source of it is added.

Riboflavin is not rapidly destroyed by heat; and it is relatively stable to oxidation and the action of acids and alkalies. In relatively pure form, especially in solution, it is changed into inactive compounds by the action of light. The riboflavin in natural feedstuffs appears to be quite stable under ordinary conditions of storage.

Pantothenic acid; 2, 4 - dihydoxy - 3, 3 - dimethylbutyryl-beta-alanine, $C_9H_{17}O_5$; occurs widely in plant

and animal tissues. It, also, is one of the water-soluble vitamins.

Pantothenic acid is necessary for growth, good feathering, and hatchability. It plays an important role in the maintenance of a normal condition of certain nerve tissues (particularly the spinal-cord) and the skin. Virtually nothing is known of the manner in which pantothenic acid functions in the animal organism.

Apparently, panthothenic acid is present in nearly all plant and animal tissues. Yeast, liver, and kidney are rich sources; next, in order, come certain leguminous seeds (e.g., peanuts), dried milk, dried milk by-products, and alfalfa meal. Some lots of cane molasses are relatively rich in this vitamin and some are relatively poor. All grains and other seeds contain some.

Pantothenic acid is destroyed by heat when dry; also, it is destroyed by acids and alkalies.

Pyridoxine, or vitamin B_6; 2-methyl-3-hydroxy-4, 5-di(hydroxymethyl)-pyridine, $C_8H_{11}NO_3$; occurs in both plants and animals. It is one of the water-soluble vitamins.

Pyridoxine is necessary for the maintenance of appetite and for growth; and apparently necessary for the proper utilization of unsaturated fat acids.

Not a great deal is known about the occurence of pyridoxine in feedstuffs, but the available information about its distribution in nature indicates that it occurs in nearly all plants and animals. Yeast is an excellent source. The grains and other seeds, especially their germs and their brans, are good sources. It has been found in fish, fish liver, mammalian liver, milk, eggs, and green, leafy vegetables.

Pyridoxine is stable to acids and heat, but is destroyed by light and oxidizing agents.

In addition to pyridoxine, there are at least two other compounds of pyridine that have many of the physiologic effects ascribed to vitamin B_6. These are pyridoxamine (2-methyl-3-hydroxy-4-hydroxymethyl-5-aminoethyl-pyridine) and pyridoxal (2-methyl-3-hydroxy-4-hydroxymethyl-5-formyl-pyridine). Any of these three compounds—pyridoxine, pyridoxamine, and pyridoxal—may be used in the formation of the coenzyme of amino-acid decarboxylase and of the glutamate-aspartate transaminase. If an animal consumes a diet that is markedly deficient in pyridoxine, it is unable to metabolize tryptophane. Thus, pyridoxine and other compounds having vitamin B_6 activity are important in protein metabolism.

Para-aminobenzoic acid; $C_7H_7O_2N$; occurs in both plants and animals. It is slightly soluble in water.

The function of para-aminobenzoic acid in the chicken is not known; nor it is definitely known that the chicken requires this vitaminlike factor. In the case of certain purified diets, however, the addition of para-aminobenzoic acid appears to have a stimulating effect on growth.

Niacin, or nicotinic acid; 3-pyridine carboxylic acid; $C_6H_5O_2N$; (also, niacinamide, or nicotinamide; 3-pyridine carboxylic acidamide; $C_6H_6ON_2$); occurs in all plant and animal tissues. It is one of the water-soluble vitamins.

Niacin is necessary for growth, good feathering, and the maintenance of a normal condition of the lining of the upper portion of the alimentary tract. Although the chicken is able to synthesize niacin, apparently it is unable to synthesize it rapidly enough to take care of its requirements under certain conditions. Niacinamide is a constituent of coenzymes I and II, which function in the transfer of hydrogen in cell respiration.

Among the richer sources of niacin are liver, yeast, rice polishings, bran, and middlings. It is present in eggs, milk, and fat meat.

Biotin, or vitamin H; 2-keto-3, 4-imidazolido-2-tetrahydrothiophenevaleric acid, $C_{10}H_{16}O_3N_2S$; occurs widely in plants and is found in small quantities in mammals and birds. Several vitamers of biotin have been reported.

Biotin is necessary for growth and hatchability, and is one of the several factors necessary for the prevention of perosis. Also, it is necessary for the prevention of a type of dermatosis.

Feedstuffs that contain biotin include liver-and-gland meals, yeast, the grains and their byproducts, cane molasses, alfalfa meal, and dehydrated grass.

Biotin deficiency is not likely to occur in chickens, when practical diets are fed. It may be produced, however, by adding a fairly large quantity of egg white to the diet. Egg white contains a material called avidin, which combines readily with biotin and inactivates it.

Biotin is heat-stable up to a temperature of about 250°C.; it also is not readily destroyed by acids and alkalies.

Folic acid, or vitamin B_c, or Lactobacillus casei factor; a group of derivatives of pteroic acid; one of which (the liver L casei factor) is N- [4- { [(2 amino-4-hydroxy-6 pteridyl) methyl] amino } benzoyl] glutamic acid, or, more simply, pteroylglutamic acid, $C_{19}H_{19}O_6N_7$; occurs in many natural products, of both plant and animal origin.

Folic acid is necessary for growth, the normal development of feathers, and the prevention of a type of anemia (macrocytic, hyperchromic) in the chick.

It is known to be present in eggs (both the white and the yolk), liver, yeast, various fermentation by-

products, grains and their byproducts, many other seeds, fish meal, meat scrap, dried milk and milk byproducts, and in the leaves of plants.

There are several folic acids, or conjugates of folic acid (or conjugates of vitamin B_c), some of which appear to differ only in the number of molecules of glutamic acid they yield when they are hydrolyzed.

Folic acid is readily destroyed by heat.

Pyracin; alpha pyracin, or 2-methyl-3-hydroxy-4-hydroxymethyl-5-carboxy-pyridine and beta pyracin, or 2-methyl-3-hydroxy-4-carboxy-5-hydroxymethyl-pyridine. The lactones of these compounds have also been referred to as pyracin. Both the acids and their lactones have been reported to be physiologically active.

Pyracin appears to be necessary for obtaining folic acid activity (growth and prevention of macrocytic, hyperchromic anemia) from certain forms of the Lactobacillus casei factor.

Choline; hydroxyethyl-trimethyl-ammonium hydroxide, $C_5H_{15}O_2N$; a constituent of complex fats.

Choline is necessary for growth, proper bone development, normal fat metabolism, egg production, and the prevention of perosis and fatty livers. There is some evidence that under certain conditions chicks are able to synthesize choline from betaine and methionine.

This vitaminlike factor is present in a large number of feedstuffs. Among the richer sources are liver meal, fish meal, yeast, wheat germ, soybean meal, tankage, and meat scrap. It is present in all grains and seeds.

Choline chloride, a commercial source of choline, yields approximately 86.78 percent of choline, when pure.

Essential fat acids, or vitamin F; linoleic acid, $C_{18}H_{32}O_2$; linolenic acid, $C_{18}H_{30}O_2$; arachidonic acid, $C_{20}H_{32}O_2$; occur as glycerides in many fats and oils.

As yet, it has not been demonstrated that the chicken requires these fat acids.

Gizzard factor, or (anti-)gizzard erosion factor. That there is an individual factor that prevents gizzard erosion is questionable. Nothwithstanding, evidence has been obtained that certain feedstuffs contain a factor—possibly a known factor or combination of known factors—that reduces the incidence and severity of gizzard erosion. Feedstuffs reported to have such an effect include alfalfa meal, oats, wheat byproducts, fresh milk, lung tissue, kale, green grass, pork liver, and kidney.

Animal protein factor. Evidence has been obtained that there is in certain products of animal origin (and in some products not of animal origin) a factor that is necessary for hatchability. Fish meal, fish solubles, liver meal, meat scrap, dried buttermilk, dried skim milk, and dried whey are all believed to be good sources. (See, also, the discussion of strepogenin, animal protein factor, and cow manure factor on page 15.)

Extractives

The class of nutrients known as extractives includes a number of different types of compounds, many of which are physiologically active. Many of the members of this class have no characteristic or property in common, as do the members of the protein, carbohydrate, or fat classes. In general, the extractives include all those organic compounds, naturally occurring in plants and animals, that are not properly classified as proteins, carbohydrates, fats, and vitamins. Originally, however, the extractives included the vitamins until the special nutritive properties of the latter were

learned and they were designated as a special class of nutrients.

Among the extratives are non-protein nitrogen compounds (other than alpha-amino acids), organic acids, enzymes, hormones, intermediate- and end-products of metabolism, and various "active principles." Individually, many of the extractives are of the utmost importance in animal physiology and nutrition.

Water

The importance of water as a nutrient cannot be stressed too strongly. It is an essential constituent of all animal cells and tissues. It is absolutely necessary for the processes of digestion; it carries materials from one part of the body to another; and it performs important functions in the regulation of the temperature of the animal organism.

An animal deprived of water dies more quickly than one deprived of all other nutrients. Its importance is further demonstrated by the fact that it accounts for about 60 per cent of the live weight of the chicken and about 65 per cent of the weight of an egg.

The weight of water consumed by a chicken depends on a number of factors, among which are: (1) The quantity of feed consumed; (2) the temperature and humidity of the environment, (3) the activity of the chicken; and (4) the nature of the feed consumed, especially its content of water, salt, and protein. The ratio of the weight of water consumed to the weight of feed consumed varies from about 2:1 to about 3:1, that is, a chicken consumes from 2 to 3 times as much water as air-dry feed.

DIGESTION AND ABSORPTION

Before the feed consumed by a chicken can be absorbed and utilized for growth, maintenance, or egg production, it first must be digested. Digestion is essentially a process in which proteins, fats, and carbohydrates combine with water and are then split into simpler compounds which may be absorbed. This process (hydrolysis) takes place through the action of substances known as enzymes. There are small quantities of enzymes in most feedstuffs, but by far the greater part of those used in digesting the feed are supplied by the chicken's body.

Passage of Feed Through The Alimentary Canal

After the feed is picked up and swallowed, it is passed on to the crop by the muscular action of the gullet. If there is no feed in the gizzard, a small part of that which first reaches the crop is passed on to the proventriculus and then, after a short pause, to the gizzard. A series of muscular contractions and relaxations takes place in the gizzard as soon as the feed reaches it. These are continued until the feed is reduced to a finely ground, pasty mass, after which it is then passed on to the small intestine.

After entering the small intestine, the mass of finely ground feed is slowly pushed toward the other end by a series of relaxations and contractions of the intestinal muscles. While being passed from one end of the small intestine to the other the feed mass is thoroughly broken up and remixed by a series of irregular and independent muscular contractions. After being pushed through the small intestine the feed mass en-

ters the large intestine and a part is slowly drawn into the ceca, and the remainder is passed on. At intervals of about 8 hours the ceca expel their contents and slowly fill again. All the while the large intestine continues to pass its contents on to the cloaca, from which, after most of the liquid portion has been absorbed, they are passed on out of the body at intermittent intervals.

Each time the gizzard empties itself, another portion of feed is passed on to it from the crop, and this continues until the crop is emptied. The length of time required for a complete emptying of the crop varies from 1 to 2 hours to as long as 16 or 17 hours, depending on the nature of the feed and the quantity consumed.

Digestion

As previously stated, digestion of the feed is brought about by the action of enzymes. There are some enzymes in the feed, but the ones that do the major part of the work of preparing the feed for absorption are supplied by the secretions of the chicken's digestive system. These secretions include (1) the saliva, secreted by the salivary glands of the mouth, (2) the mucus, secreted by the mucous glands of the crop, (3) the gastric juice, secreted by the proventriculus, (4) the pancreatic juice, secreted by the pancreas, (5) the bile, secreted by the liver, and (6) the intestinal juice, secreted by the small intestine.

The saliva has a pH of 6.7 to 6.9. It always contains some amylase. The presence of small quantities of lipase has been reported.

The mucus of the crop has a pH of 4.4 to 4.9. This secretion probably contains no enzymes, but the presence of lactase in the wall of the crop and in the contents of the crop has been claimed.

The gastric juice has a pH of 4.0 to 4.4; notwithstanding, it has been reported that the pH of the contents of the gizzzard may vary from 2.7 to 3.6. Pepsin is always present in the gastric juice.

The pancreatic juice is nearly neutral in reaction, but at times is slightly acid. It contains amylase, lipase, and trypsin.

The bile usually is slightly acid. It contains no digestive enzymes, but it aids in emulsifying fats and, thus, facilitates the action of lipase; it also aids in the absorption of the fat-soluble vitamins.

The intestinal juice is approximately neutral in reaction. It is the source of amylase, erepsin (åminopolypeptidase and dipeptidase), maltase, and sucrase.

Undoubtedly there are enzymes, in addition to those mentioned above, in the pancreatic and intestinal juices. Among those probably present are carboxypolypepidase (in the pancreatic juice) and polynucleotidase and nucleotidase (in the intestinal juice).

Although the gizzard contents are strongly acid, the reaction of the feed mass becomes progressively alkaline as it passes through the small intestine. Thus, the pH in the duodenum is about 6.3 on the average, but that of rectum may be as high as 8.2 and has an average value of about 7.4. The pH in the jejunum may vary from 6.0 to 8.0, with an average value of about 7.0, and that in the ileum, from 7.0 to 8.4, with an average value of about 7.6.

No digestion takes place in the mouth, because the feed is there such a very short time. Some digestion takes place in the crop, as a result of the combined effects of moisture and warmth supplied by the chicken, the enzymes originally present in the feed, and the amylase in the saliva. In any case, the quantity of feed actually digested in the crop is small.

The rate of digestion promptly increases soon after the feed reaches the gizzard, but, by far, the greater part of the digestion takes place in the small intestine after the feed has been mixed with the gastric juice of the proventriculus and ground by the gizzard. The initial hydrolysis of proteins to proteoses and peptones, by pepsin, begins in the gizzard and continues in the small intestine.

It is in the small intestine that the amylase hydrolyzes the starches and dextrins to maltose and, in turn, the maltase continues the hydrolysis by splitting maltose into glucose. Here, also, sucrase brings about the hydrolysis of sucrose to glucose and levulose.

Somewhat farther along in the small intestine proteins, proteoses, and peptones are hydrolyzed into polypetides by the trypsin and, in turn, erepsin continues the hydrolysis to simpler peptides and amino acids.

The digestion of fat by lipase begins in the gizzard and continues as the feed passes on into the large intestine.

No digestive enzymes are secreted by the large intestine, but the processes of digestion that began in the small intestine continue for a time as the feed passes through the large intestine. There is considerable absorption of water, and some absorption of digested feed from the large intestine.

Some digestion and much fermentation take place in the ceca. It is here that the greater part of the small quantity of crude fiber digested by the chicken is broken down into simpler compounds. Moreover, it is not unlikely that the fermentations in the ceca of the chicken produce vitamin K and at least some of the so-called B-vitamins.

Digestive changes are extremely rapid in the chicken; in as little as 1½ to 2 hours after a portion of the

feed leaves the crop it may be digested, and the indigestible residue voided. However, for the complete digestion of a full meal, as few as 10 hours or as many as 18 hours may be required; the average time is approximately 14 hours, but it may be appreciably less when nothing but a wet mash is fed.

Absorption

No absorption, even of such simple substances as water, salt, and glucose, takes place from the crop. Evidence of absorption from the esophagus, proventriculus, and gizzard has not been obtained. Most of the absorption of the products of digestion takes place from the small intestine; however, there is some absorption from the ceca and large intestine.

The small intestine is structurally adapted for absorption; its lumen is literally lined with small finger-like projections called villi. Each villus has a lymph capillary and a close network of blood capillaries.

The products of the digestion of fat—glycerol and fat acids—are absorbed mostly by way of the lymph capillaries, but a small portion is probably absorbed by the blood capillaries. In any case, bile is necessary for the normal absorption of fat acids. During or immediately after absorption, the glycerol and fat acids are recombined to form fats. The recombined fats are carried on into the thoracic duct from which they are emptied into the blood stream.

The products of the digestion of proteins and carbohydrates, and dissolved salts, are absorbed by the blood capillaries and then pass on into the portal vein, by which they are carried to the liver.

Grit and the Gizzard

The chief, and perhaps only, function of the gizzard is to grind feed. The truth of this statement was con-

vincingly demonstrated by some experiments, conducted at the Beltsville Research Center, Beltsville, Maryland, in which chickens lived as long as 4 years after their gizzards had been removed surgically. It was found, however, that the chickens without gizzards did not digest so much of their feed, unless it was finely ground, as did other chickens from which the gizzards had not been removed.

In the same series of experiments the effect of grit on the digestibility of feed was studied. It was found that although chickens can digest whole grain without the aid of grit, the percentage digested is increased, if there is some grit in the gizzard. In general, the digestibility of whole grains and other seeds may be increased as much as 10 per cent and that of mashes about 3 per cent, if the chickens have access to grit. When approximately equal quantities of grain and mash are fed, the presence of grit in the gizzard may be expected to increase the digestibility of the total feed consumed by as much as 6 or 7 per cent.

The gizzard grinds feed both by crushing it and by tearing it apart. Grit aids the gizzard in grinding feed by providing hard, smooth surfaces, between which the particles of feed may be crushed. Nevertheless, the gizzard is able to grind feed without the aid of grit; but in the absence of grit much less of the feed is crushed, a large part of it is literally torn apart by the rubbing together of the rough internal surfaces of the gizzard. Because of the manner in which grit aids the gizzard in grinding feed, grit that is sharp-cornered is of little value until the sharp corners and edges have been worn away, and smooth surfaces have been provided, between which the particles of feed may be crushed. The gizzard has enormous crushing power. It has been estimated that pressures up to several hundred pounds per square inch are developed by the muscular contractions of the gizzard.

Experiments on the economy of feed utilization by the growing chicken have indicated that the energy required for grinding feed by the gizzard is less when some grit is present than when it is totally absent. In spite of the fact that grit is not essential to the chicken, it must be conceded that it plays an important role in the digestion of feed by this species.

The results of the experimental work referred to in the preceding paragraphs clearly showed that it is a worthwhile practice to supply grit to chickens that are so reared and managed that they do not have access to the soil. Careful consideration, however, should be given to the matter of selecting the grit that is to be fed; its physical properties are especially important. Any material that is to be used as grit should be nonfriable (i.e., not easily fractured and broken into small pieces) and sufficiently hard to withstand the pressures to which it is subjected in the gizzard.

Bulk and Fiber

As a general rule, excessively bulky feed mixtures and those of unusually high fiber content are not well utilized; neither are the very concentrated feed mixtures that have a comparatively small bulk and contain almost no fiber. Some of the more bulky feedstuffs in the ordinary feed mixtures given to chickens are: bran, distillers' dried grains, alfalfa meal, oats, barley, and hominy feed. A few of the less bulky feedstuffs are: polished rice, wheat, corn, peas, millet, dried skim milk, dried buttermilk, fish meal, and meat scrap.

When the bulkiness of feedstuffs is compared with their fiber content, it is found that there is no marked relationship between the two. For example, although wheat bran is one of the bulkiest of feedstuffs included in feed mixtures for chickens, it contains less than a

third as much fiber as do sunflower seeds, which are one of the less bulky feedstuffs.

There is some evidence that the presence of a small quantity of indigestible and somewhat bulky material in the intestines facilitates both the digestion and absorption of the digestible portion. Ordinarily, the crude fiber in the feed serves as a source of such material, because the chicken does not digest crude fiber readily. It is not possible to state just how much crude fiber a diet should contain, because the physical properties of crude fiber varies from one feedstuff to another. Ordinarily, 3 to 5 per cent is enough, although in some cases the diet may contain as much as 10 to 12 per cent without having any markedly detrimental effect.

METABOLISM

Metabolism is a term that includes all the chemical changes that take place in the animal organism. The materials that participate in these changes are the tissues of which the animal is composed, the feed and water consumed, and the oxygen in the air inhaled. Reference is often made to total, or energy, metabolism; protein metabolism; carbohydrate metabolism; fat, or lipid, metabolism; mineral metabolism; water metabolism; or to the metabolism of some individual compound. Energy metabolism, for example, refers to all the changes that result in the liberation of energy in the animal organism; protein metabolism refers to all the changes that protein undergoes after it is ingested; and glucose metabolism refers to all the changes this individual compound undergoes after it is ingested or is formed in the organism. Energy metabolism, however, includes the metabolism of protein, fat, and carbohydrate, and, as well, the metabolism of any compound or substance that results in the liberation of energy, even though it may not be classified properly as protein, carbohydrate, or fat.

A large part of the feed consumed by a chicken is used for the production of energy; another part is used for the building of new tissues (i.e., for growth and egg production) and the synthesis of hormones and enzymes; some is stored as fat and glycogen; and the remainder is voided in the excrement. Some of the energy is used in performing work (muscular activity), some in bringing about chemical changes, and the remainder appears as heat.

Energy Metabolism

The rate of energy metabolism, per unit of live weight, is comparatively high in the chicken; it exceeds that of the energy metabolism in our larger domestic animals. It increases slightly, after hatching, until an age of about two weeks is reached; thereafter it declines—at first quite rapidly and then more slowly—until it becomes relative constant. Figure 1 illustrates the changes that take place in the basal energy metabo-

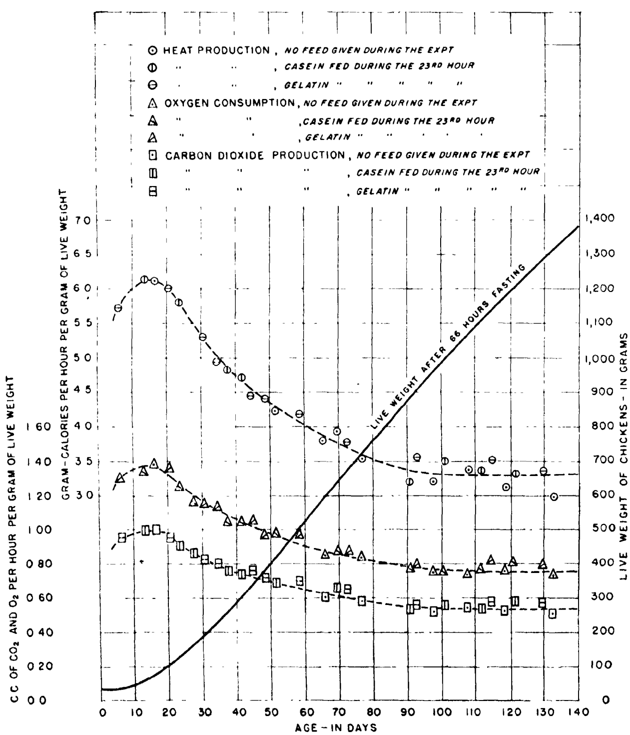

Fig. 1. Effect of age on the average basal energy and gaseous metabolism of male Rhode Island Red chickens (between 38 and 46 hours after feeding casein or gelatin, and/or between 62 and 70 hours after last regular feed was consumed). (Data of Barrott, Fritz, Pringle, and Titus in Jour. of Nutr. 15(2):145-167; 1938.)

lism of male Rhode Island Red chickens between hatching and the age of 140 days.

When an animal burns one gram of "average" carbohydrate, approximately 4.1 kilogram-calories of heat is produced and about 0.6 gram of water is formed; when it burns one gram of "average" fat, approximately 9.4 kilogram-calories of heat is produced and about 1.07 grams of water is formed. When an animal burns one gram of "average" protein, the quantities of heat produced and of water formed depend on the nature of the nitrogenous end products. In the chicken, the chief nitrogenous end product of protein metabolism is uric acid, whereas in most other species of animals it is urea. Accordingly, in the chicken the burning of one gram of "average" protein produces only about 3.8 kilogram-calories of heat and leads to the formation of about 0.47 gram of water, whereas in most other species of animals it produces about 4.3 kilogram-calories of heat and leads to the production of only about 0.4 gram of water.

Protein Metabolism

After the amino acids resulting from the digestion of protein enter the blood stream, they are carried to the various tissues of the body. Some are used for the building of new tissues (e.g., in growing chicks) or the "repair" of existing tissues and the formation of certain hormones; those that are not used in this manner are broken down into comparatively simpler substances, from some of which, in turn, glucose and fat may be formed. As much as 58 per cent of the protein absorbed (in the form of amino acids) may be converted into glucose or into glucose and fat.

As was stated in the discussion of energy metabolism, the end products of the metabolism of protein are not the same in the chicken that they are in most other

species of animals. However, some of the intermediate steps in the metabolism of protein are presumably the same in most classes of animals. In any case, even though some urea is formed, the chief end product of the metabolism of amino acids in the chicken is uric acid. As in other classes of animals, the end products of the breakdown of pyrimidine and purine bases is uric acid and carbon dioxide. The respiratory quotient for the burning of "average" protein in the chicken is about 0.7, whereas in most other classes of animals it is about 0.8.

Carbohydrate Metabolism

After the simple sugars that result from the digestion of carbohydrate enter the circulation and reach the liver, they are, for the most part, converted into glycogen. Thus, glucose, levulose, and galactose are all converted into glycogen. Some of the glucose, however, is passed on to the various tissues where it is burned for the performance of work or the production of heat. Glycogen is stored largely in the liver, but to some extent in other tissues. Glycogen is readily converted into glucose, which in turn enters the circulation and is carried to those tissues in which it is needed.

Various enzymes, including phosphatase, dehydrogenase, and decarboxylase, participate in the metabolism of glucose. The ultimate end products of this metabolism are carbon dioxide and water. The respiratory quotient for the burning of carbohydrate in the chicken is the same as it is in other animals, i.e., 1.0.

Carbohydrate, in excess of that which can be stored as glycogen, is either burned or converted into fat and stored as a future source of energy.

Fat Metabolism

The glycerol resulting from the digestion of fat is metabolised as carbohydrate. The fat acids are oxidized

step-wise through the action of oxidase. The ultimate end products of their metabolism are carbon dioxide and water. The respiratory quotient for the burning of an "average" fat is the same in all animals, i.e., about 0.7. Thus, in the chicken, the respiratory quotient for the burning of "average" fat is essentially the same as that for the burning of "average" protein.

Fat, in excess of that which can be burned for the production of heat, is stored as such in the body. In the chicken, large quantities of fat are stored in the abdominal cavity—in the mesentary and around the gizzard, especially the latter.

HORMONES AND NUTRITION

More than 30 hormones have been described. Of these, *at least* 11 are elaborated by the pituitary, 10 by the reproductive systems, 4 by the adrenal glands, and 1 each by the thyroid, thymus, pineal, parathyroids, pancreas, and duodenal mucosa. In addition, there is a fairly large number of chemical compounds that have hormonal activity or affect the secretion of hormones.

Some of the hormones, e.g., secretin, cholecystokinin, enterogastrone, and gastrin, act directly on the alimentary system. Others, e.g., thyroxine, insulin, epinephrine, parathormone, the "blood-sugar-raising" principle, and the ketogenic principle, have direct effects on metabolism. Still others, e.g., the various hormones of the pituitary and the reproductive systems, have more or less indirect effects on metabolism. Virtually all the hormones have either direct or indirect effects on metabolism.

Secretin.—This hormone is liberated from the walls of the duodenum and is carried by the blood to the pancreas, where it causes the pancreas to secrete.

Cholecystokinin.—This hormone probably comes from the walls of the duodenum; it causes the gall bladder to contract and empty its contents.

Enterogastrone.—Whether or not the chicken produces this hormone is not known. In those animals in which it is produced it has an inhibitory effect on both gastric secretion and motility.

Gastrin.—This hormone is believed by some persons to be identical with histmine; it stimulates the secretion of hydrochloric acid.

Thyroxine.—This hormone is one of the amino acids. It appears to have a stimulating effect on all metabolic processes. In any case, the basal metabolism may be greatly increased by the administration of thyroxine. The formation of thyroxine is inhibited by the administration of thiourea and thiouracil.

Insulin.—One of the most important factors in the regulation of carbohydrate metabolism is insulin. This hormone is elaborated in the pancreas. When insufficient insulin is produced, there is an increase of sugar in the blood, the glycogen stores of the liver and muscles are greatly reduced, and fat and the acetone bodies of fat metabolism accumulate in the blood.

Epinephrine.—Exceedingly small quantities of this hormone are effective. It is elaborated in the meduella of the adrenal glands. Its normal concentration in the blood is of the order of 1 to 2 parts per billion. This hormone plays an important role in carbohydrate metabolism; in particular, it catalyzes the transformation of glycogen into glucose.

Parathormone.—The mineral metabolism of animals — especially the metabolism of calcium and phosphorus—is strikingly affected by either an underproduction or an overproduction of parathormone. In either case, there is decalification of the skeleton.

The hormones of the pituitary.—The two diabetogenic principles of the pituitary have more or less direct effects on carbohydrate metabolism. One of these two, the blood-sugar-raising principle, is antagonistic to insulin in controlling the level of sugar in the blood. The other one, the ketogenic principle, stimulates the production of ketone bodies, especially beta-hydroxybutyric acid.

Most of the other hormones of the pituitary have effects on the secretion of hormones by other glands.

For example, the thyrotropic principle regulates the secretion of thyroxine; the parathyrotropic principle regulates the development of the cells of the parathyroid gland and, hence, the production of parathormone; the adrenotropic principle controls the production of the hormones of the adrenal cortex, and the pancreotropic principle either regulates the formation of insulin or controls its action.

With the exception of the so-called growth hormone, the remaining hormones of the pituitary are concerned, in one way or another, with the functioning of the reproductive system.

Effect of Estrogens and Other Compounds on Fat Metabolism

Since 1938, a number of studies have been made of the effect of the estrogens on fat metabolism in the chicken. The effect of other compounds, such as thiourea, has also been studied.

Estrogens.—In general, the administration of estrogens, either by injection, implantation, or feeding, causes an increase in the fat and calcium content of the blood. In male chickens, the continued administration of estrogens (either natural or synthetic) causes the comb to shrivel, become anemic, lose its turgor, and droop. This effect of the estrogens may be prevented by the administration of androgens (e.g., by feeding cow manure that has been dried at a temperature slightly less than 45° C. or by rubbing a very small quantity of methyl testosterone into the comb).

Among the estrogens that have been tested are: stilbestrol, diethylstilbestrol, the dimethyl ether of diethylstilbestrol (or dianisylhexene), and the natural estrogen. The injection of as little as 1.0 mg of diethylstilbestrol into a male chicken will cause the fat content of the blood to increase to a value 4 to 5 times

the normal value. By giving as many as 6 injections of 4 mg each, the fat content of the blood may be increased more than forty fold, and the calcium content of the blood increased about four fold. It has been reported that by the administration of the natural estrogen the fat content of the blood of male chickens was increased more than sixty fold.

Estrogens have been used experimentally for increasing fat deposition in chickens and improving their market grade. The dimethyl ether of diethylstilbestrol, when fed mixed with the feed (50 mg per pound) for two weeks, has been reported to improve greatly the market grade of chickens, regardless of their age. The consumption of feed was increased, in some instances, as much as 35 per cent. Implants of diethylstilbestrol and of stilbestrol (15 to 25 mg) also have been reported to have similar effects. The implant method of administering the estrogens for the improvement of the market grade of poultry appears to be more efficient than the other methods.

Some of the claims made for the use of the estrogens in finishing chickens for market are: (1) It increases the fat content of the muscle tissues; (2) the dark meat becomes lighter in color and more tender; (3) the chickens acquire a bleached out, "milk-fed," appearance; and (4) the flesh becomes more "highly flavored."

Thyroxine and thyroactive iodoprotein.—It has been claimed that there is an optimum dosage of thyroxine or of thyroactive iodoprotein for stimulating growth. That, undoubtedly, is true, but the optimum dosage varies greatly from one individual to another. If the quantity is too small, it has no effect on the increase in weight of a growing animal; and if the quantity is too large, it has a depressing effect on growth. Accordingly, it would be difficult, if not im-

possible to incorporate in a feed mixture a quantity of thyroxine or thyroactive iodoprotein that would be optimum for stimulating the growth of all the individual chickens in a given flock. However, it should be possible, by trial, to select for a given strain of chickens a level of intake that, on the average, would give optimum stimulation.

In general, each chicken or other animal has a thyroid gland that is capable of producing the quantity of thyroxine that is required by that particular individual, if its feed contains an adequate but not excessive quantity of iodine. Of course, in any flock there is almost certain to be a few individuals that do not have sufficient thyroid tissues as well as a few that have too much. In feeding flocks, however, one must deal with the "average" chicken and not with unusual individuals. Accordingly, it is better to supply an adequate quantity of iodine in the feed, so that the full capacity of each chicken's thyroid gland will be utilized. In this way, there is less likelihood of overstimulating the chickens.

When an animal produces, or is given, more thyroxine than it needs, it will not fatten. As a matter of fact, the actively growing chicken deposits but little fat in its tissues. When a healthy chicken has ceased to grow, however, it may be fattened readily.

Thiouracil and thiourea.—Because thiouracil and thiourea inhibit the production of thyroxine, studies have been made of their effect on fat deposition in the chicken. Thiourea is much more toxic than thiouracil and, apparently, is not satisfactory for increasing fat deposition. On the other hand, when thiouracil is included in the feed of growing chickens, at a level of 0.2 per cent, it tends to stimulate fat deposition and to improve the market grade of the carcasses. If fed for short periods (2 or 3 weeks) it tends to have no ap-

preciable effect on rate of growth, but if fed for longer periods (5 weeks or more) it tends to depress growth. Large doses of thiouracil have been reported to produce perosis in growing chicks.

A serious objection to the use of thiouracil in the fattening of chickens intended for human consumption is that some of it may be retained in the tissues of the chickens. In any case, it has been demonstrated that some of the thiouracil ingested by laying chickens is transmitted to the chicks through the eggs. Poultry meat (or eggs) containing thiouracil would be a definite hazard to public health.

Thyroxine, Iodocasein, and Egg Production

The results of experiments on the feeding of desiccated thyroid, which contains thyroxine, have not been in full agreement, probably because different quantities were fed and chickens of different ages were used. Large quantities, however, always brought on a molt and decreased egg production. In some instances, small quantities (0.005 g to 0.1 g per day) seemed to increase egg production, especially in chickens that were at least one year old.

Work with iodocasein, which contains some thyroxine, has given more promising results than the earlier work with desiccated thyroid. It has been reported, for example, that 10 g of iodocasein (containing about 2.7 per cent of thyroxine) per 100 pounds of feed tends to increase egg production, especially during the last half of the laying year. However, 20 g of iodocasein per 100 pounds of feed caused a decrease in egg production. In other work, in which the feed contained 15 g of iodocasein per 100 pounds, there seemed to be an increase in the strength of the eggshells.

In general, in northern latitudes egg production per chicken reaches its maximum in March, April, or May —depending on the date of hatch and the climate— and then declines. With the decline in egg production there usually is a decrease in the weight and strength of the eggshells. This change in the eggshells tends to be most marked when the environmental temperatures are high. It, therefore, is of interest that there is a decrease in the production of thyroxine when the environmental temperature increases.

It is not improbable that the judicious use of iodocasein, or of thyroxine, will permit the poultryman to obtain a higher production from his flock during the latter part of the laying year and, at the same time, obtain eggs that have better shells. It should be pointed out, however, that most feedstuffs used in the feeding of poultry contain less than 0.1 part per million (0.00001 per cent) of iodine and that only a few of them, e.g., fish meal and some lots of meat scrap, contain as much as 1 part per million (0.0001 per cent.) Accordingly, it is not unlikely that practically the same results can be obtained by using feed mixtures that contain about 5 parts per million (0.0005 per cent) of inorganic iodine, as have been obtained by using iodocasein. In any case, there is less danger of overstimulating the birds when inorganic iodine is used than when thyroxine or iodocasein (thyroactive iodoprotein) is used. (See discussion of thyroxine and thyroactive iodoprotein, page 53.)

UTILIZATION OF FEED

The efficiency with which feed is utilized by chickens is of the utmost importance to the poultryman, because the cost of the feed accounts for 50 to 60 per cent, or even more, of the total cost of producing either meat or eggs. Although a reduction of as much as 20 per cent in the quantity of feed required to produce a pound of meat or a dozen eggs may mean a difference of only 10 to 12 per cent in the total cost of production, such a difference often determines whether a profit is to be made or a loss is to be sustained.

Growth

The rate of growth of an animal is dependent on many factors, but is determined largely by the species, sex, and age of the animal, the adequacy of its diet, and the quantity of feed it consumes. Some species of animals grow more rapidly than others; for example, the duck grows more rapidly than the chicken. Among chickens and other kinds of poultry, the males tend to grow more rapidly than the females. The absolute rate of growth (gain per unit of time) of an animal increases with age, for a time, and then decreases. The relative rate of growth (gain, expressed as per cent of the weight) decreases with age, slowly at first and then very rapidly. A fully adequate diet supports a more rapid rate of growth than a diet that is markedly deficient in one or more of the essential nutrients. In general, the more feed a growing animal consumes, the more rapidly it gains in weight.

A young, actively growing animal normally makes a larger gain in live weight, per unit weight of feed consumed, than does an older one. That is to say, as an

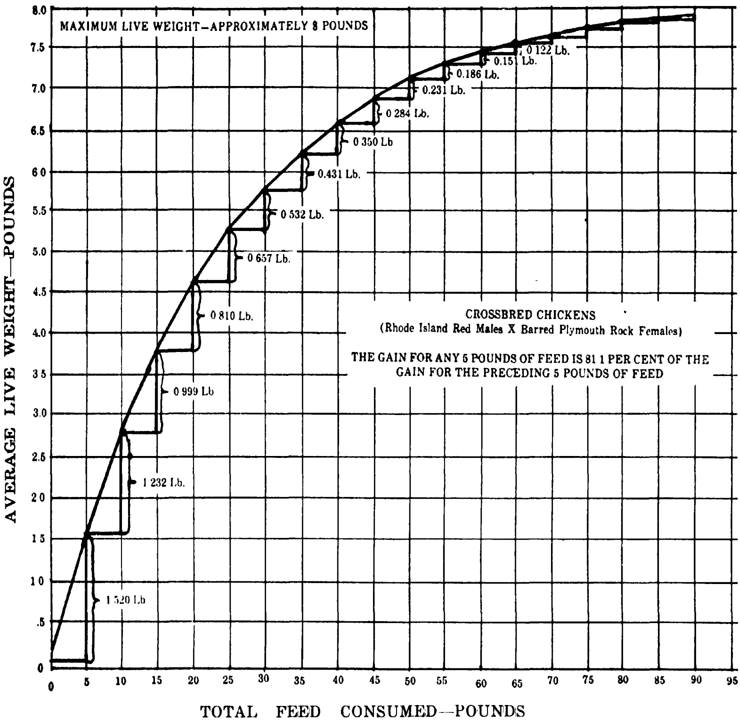

Fig. 2. The relationship between live weight and cumulative feed consumption in crossbred chickens (the male offspring resulting from mating Barred Plymouth Rock females with Rhode Island Red males).

animal increases in weight, the gain it makes, on a given quantity of feed, decreases. The relationship between live weight and feed consumption in the growing animal follows a rather simple, definite law, known as the law of diminishing returns. The way in which this law operates is shown in figure 2, in which the average live weight of a group of male crossbred chickens is plotted against cumulative feed consumption.

The figures directly beneath the curve in figure 2 are the pounds of gain in live weight that resulted

from the consumption of each successive 5 pounds of feed. An examination of figure 2 readily shows that the second 5 pounds of feed produced only 81.1 per cent as much gain as did the first 5 pounds, that the third 5 pounds produced only 81.1 per cent as much gain as did the second 5 pounds, and so on. As a result of the operation of the law of diminishing returns, it will be seen that the twelfth 5 pounds of feed produced only about one-tenth as much gain as did the first 5 pounds. If, in figure 2, the gains were shown for each pound of feed instead of for each 5 pounds, it would be found that the second pound produced only 95.9 per cent as much gain as did the first pound, the third pound only 95.9 per cent as much gain as the second pound, and so on.

The reason that successive equal weights of feed do not produce equal gains is, briefly, as follows: The daily feed consumption of a growing chicken increases as the live weight increases, but the former does not increase so rapidly as the latter. Furthermore, as a chicken becomes heavier, more and more of its feed is required for maintenance; and so, an increasingly smaller percentage of feed is available for growth. The net result is that the gain, resulting from each successive unit weight of feed, becomes progressively smaller.

Inasmuch as a rather large share of the feed consumed by a growing chicken is used for maintenance, one might conclude that the efficiency of feed utilization (gain per unit weight of feed) is highest when a chicken eats all the feed it can. Such, however, is not the case; nor is it the case in several other species of animals, if not in all species. As a matter of fact, the largest gains per pound of feed are made when the feed consumption of a chicken is restricted to only 50 to 70 per cent of the normal consumption. The effect of level of feed intake on efficiency of feed utilization is illustrated in table 1.

Table 1. Effect, in male chickens of the heavier breeds, of the level of feed intake on the relative efficiency of utilization of feed for growth, the relative maximum live weight attained, the relative quantity of feed required for attaining the maximum live weight, and the relative length of time required to attain maximum live weight on a diet containing about 19.4 per cent of crude protein.

Level of feed intake as per cent of full feed	Relative average efficiency of utilization of feed for growth	Relative maximum live weight[1] attained	Relative quantity of feed required for attaining maximum live weight[1]	Relative length of time required to attain maximum live weight[1]
	Per cent	Per cent	Per cent	Per cent
20	90.7	19.1	21.1	105.1
30	93.3	51.1	54.7	103.6
40	97.2	77.7	79.9	101.9
50	100.0	100.0	100.0	100.0
60	99.1	114.9	116.0	98.1
70	96.8	127.7	131.0	94.9
80	94.8	138.3	145.9	89.9
90	93.1	148.9	159.9	82.0
100	92.6	156.6	169.2	73.2

[1]This refers to the maximum live weight that is eventually attained after a prolonged period of feeding at the levels indicated in the first column.

The data in table 1 were obtained in a feeding experiment in which a number of groups of male chickens were fed, at different levels of feed intake, an all-mash diet that contained about 19.4 per cent of protein. According to the data in this table, the feed apparently was utilized most efficiently when the level of feed intake was between 50 and 60 per cent of full feed. However, other experiments conducted by the writer indicated that the maximum efficiency may, at times, occur between the 60- and 70-per cent levels. In any case, it has been demonstrated that growing chickens make smaller gains per pound of feed when they are allowed to eat all they want than when their consumption of feed is partially restricted. This is true, regard-

less of whether the feed contains as little as 13 per cent of protein or as much as 25 per cent.

Unfortunately, however, it is difficult to take advantage of the fact that feed is utilized more efficiently at levels of intake between 50 and 70 per cent of full feed than it is at full feed. Mortality tends to be higher when the feed intake is markedly restricted than when it is not restricted. Moreover, in the practical production of chickens for meat, it would not be economical to feed at a level of intake that is only 50 to 70 per cent of full feed, even though a greater gain per unit weight of feed is obtained. The data in table 1 clearly show why this is true. According to these data it would require more than twice as much time, with the same brooding and housing facilities, to produce the same weight of live chickens at the 50 per cent level of feed intake as it would at full feed. Or, to make a comparison of the results in another way, by feeding only 69 per cent more feed at the full feed level of intake one would get 57 per cent more live weight, in about 27 per cent less time, than he would get by feeding at the 50 per cent level. Furthermore, the chickens that would be produced on the lower level of feed intake would have little fat and, hence, would have a lower market value per pound than those produced on full feed.

Under ordinary conditions, male chickens are somewhat more efficient in their utilization of feed for growth than are the females of the same breed and strain. It has been found, also, that chickens of some breeds utilize their feed more efficiently than those of other breeds to reach a given live weight; the same is true of other kinds of poultry. This is clearly shown in table 2, in which is given the quantity of feed required by three different kinds of poultry—including three breeds of chickens—to reach different live

weights from 0.5 to 5 pounds. However, it should be noted that the data in table 2 cannot be used for making **exact** comparisons of the efficiencies of the different kinds of poultry in utilizing feed for growth, because no two of the diets that were fed were the same. Nevertheless, diets suitable for each kind of poultry were fed; and, hence, these data indicate in a general way the relative abilities of chickens, turkeys, and ducks to utilize feed for growth.

Table 2. The feed required to obtain certain selected average live weights with different kinds of poultry.

Average live weight	Kind of poultry and quantity of feed required per bird					
	White Leghorns (males and females)[1]	White Leghorns (males)	Crossbreds[2] (males)	Rhode Island Reds (males)	Turkeys[3] (males)	White Pekin ducks (males and females)[1]
Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
0 5	1 38	1 30	1.29	1 12	0 95	0 83
1.0	3.18	3.00	2 91	2 53	2 20	2.01
1.5	5 27	4 94	4 65	4 05	3.49	3 28
2.0	7.75	7 21	6 52	5 69	4.83	4.66
2 5	10 80	9 93	8.56	7 49	6.21	6.17
3.0	14 75	13.34	10.78	9 46	7.65	7.83
3.5	20 39	17 91	13.24	11 66	9 15	9.68
4.0		24 84	15 97	14 13	10 70	11.77
4.5		39.75	19 07	16 95	12.32	14.17
5 0			22 62	20.25	14 02	16 99

[1]For a group containing approximately the same number of birds of each sex.
[2]The male offspring resulting from mating Barred Plymouth Rock females with Rhode Island Red males.
[3]Several different breeds from parent stock which had been selected for small size.

The relationship between live weight and feed consumption is shown in another way in table 3, in which are given the live weights of different kinds of poultry when first fed and their live weights after they had consumed from 1 to 15 pounds of feed. The gain in live weight for each pound of feed is also given. This table readily shows that in a group of White Leghorn males and females, containing approximately the same number of chickens of each sex, the gain produced by any given pound of feed, after the first, is about 92.8 per cent as great as that produced by the preceding pound

Table 3. The relation between live weights and feed consumption in different kinds of poultry.

Feed consumed per bird	White Leghorns[1] (males and females)		White Leghorns (males)		Crossbreds[2] (males)		Rhode Island Reds (males)		Turkeys[3] (males)		White Pekin ducks[1] (males and females)	
	Average live weight	Gain in live weight	Average live weight	Gain in live weight	Average live weight	Gain in live weight	Average live weight	Gain in live weight	Average live weight	Gain in live weight	Average live weight	Gain in live weight
Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
0	0.072	0.000	0.072	0.000	0.077	0.000	0.077	0.000	0.111	0.000	0.126	0.000
1	.387	.315	.404	.332	.407	.330	.456	.379	.522	.411	.574	.448
2	.681	.294	.713	.309	.724	.317	.817	.361	.923	.401	.996	.422
3	.952	.271	1.000	.287	1.027	.303	1.159	.342	1.313	.390	1.393	.397
4	1.205	.253	1.266	.266	1.318	.291	1.485	.326	1.693	.380	1.765	.372
5	1.439	.234	1.514	.248	1.597	.279	1.795	.310	2.063	.370	2.116	.351
6	1.656	.217	1.744	.230	1.865	.268	2.089	.294	2.424	.361	2.446	.330
7	1.858	.202	1.957	.213	2.121	.256	2.369	.280	2.776	.352	2.756	.310
8	2.045	.187	2.155	.198	2.367	.246	2.634	.265	3.118	.342	3.048	.292
9	2.219	.174	2.340	.185	2.603	.236	2.887	.253	3.452	.334	3.332	.274
10	2.380	.161	2.511	.171	2.829	.226	3.128	.241	3.777	.325	3.580	.258
11	2.529	.149	2.670	.159	3.046	.217	3.356	.228	4.094	.317	3.822	.242
12	2.668	.139	2.818	.148	3.254	.208	3.573	.217	4.402	.308	4.050	.228
13	2.797	.129	2.955	.137	3.454	.200	3.780	.207	4.703	.301	4.265	.215
14	2.916	.119	3.083	.128	3.645	.191	3.976	.196	4.995	.292	4.467	.202
15	3.027	.111	3.201	.118	3.829	.184	4.162	.186	5.281	.286	4.656	.189

[1]For a group containing approximately the same number of birds of each sex.
[2]The male offspring resulting from mating Barred Plymouth Rock females with Rhode Island Red males.
[3]Several different breeds from parent stock which had been selected for small size.

of feed; in White Leghorn males it is about 92.9 per cent as great; in the crossbred males it is about 95.9 per cent as great; and in the Rhode Island Red males, the turkey males, and the mixed White Pekin males and females, it is about 95.1, 97.4, and 94.0 per cent, respectively, as great.

Table 4. The approximate ages at which certain selected live weights are reached in two common breeds of poultry.

Average live weight	Kind of chicken and age at which certain live weights are reached				
	White Leghorns			Rhode Island Reds	
	Females	Males	Capons	Females	Males*
Pounds	Weeks	Weeks	Weeks	Weeks	Weeks
0.5	4.0- 5.3	4.0- 5.3	4.0- 5.3	3.9- 5.1	3.9- 5.1
1.0	6.6- 8.4	6.0- 8.2	6.2- 8.6	5.9- 8.0	5.8- 7.9
1.5	9.0-11.0	7.8-10.3	8.4-11.0	7.7-10.4	7.6-10.1
2.0	11.7-14.1	9.5-12.3	10.4-13.3	9.5-12.5	9.2-11.9
2.5	14.7-17.7	11.2-14.5	12.3-15.5	11.2-14.5	10.7-13.8
3.0	18.1-22.4	13.6-17.0	14.7-18.1	13.2-16.6	12.2-15.5
3.5	23.6-31.0	16.7-20.3	17.5-21.1	15.6-18.6	13.7-17.1
4.0	....	20.4-25.3	20.6-25.3	18.3-21.2	14.9-18.7
4.5	....	25.7-36.0	24.6-32.0	21.3-24.7	16.1-20.2
5.0	... ..	.. ... .	. .	25.0-29.8	17.3-21.9

*Rate of growth of capons and cockerels of the heavy breeds is approximately the same up to 28 weeks of age.

The efficiency of feed utilization for growth varies not only with the breed and kind of poultry but also with the type of diet consumed and with the temperature of the environment. Nevertheless, the information contained in tables 2 and 3, and that supplied by figure 2, is of value to the poultryman who wishes to know approximately how much feed ordinarily will be required to obtain a given average increase in live weight. For those who may wish to know at approximately what age a given live weight is reached, table 4 is presented. It contains data on White Leghorns and Rhode Island Reds.

Egg Production

A small part of the feed consumed by a pullet is used for growth and the remainder for maintenance and egg production. In the yearling hen, the feed is used chiefly for the last two purposes but some is used for regaining weight lost during the molt that usually takes place during the last few months of the pullet year.

Studies of the feed requirements of laying chickens have shown that after enough feed has been consumed to take care of the growth and maintenance requirements, approximately 0.09 pound of additional feed must be consumed for each egg that is laid. Thus, it is readily apparent that of two chickens of equal live weight, the one that lays the larger number of eggs requires the more feed. If one of two such chickens lays only 60 eggs in a year and the other lays 160 eggs, the latter will require about 9 pounds more feed than the former.

Roughly, the quantity of feed required to maintain a chicken one year increases about 10 pounds for each increase of 1 pound in the chicken's live weight. Hence, it takes approximately 10 pounds more feed per year to maintain a 5.5-pound hen than it does to maintain a 4.5-pound hen. According to experiments conducted by the writer at the Beltsville Research Center, a 3.5 pound chicken has a maintenance requirement of 0.14 pound of feed per day, or about 51.1 pounds of feed per year. The maintenance requirement of chickens of other live weights may be estimated with a fair degree of accuracy by assuming that the maintenance requirement is proportional to the 0.73 power of the live weight.

There is some disagreement about the exact quantity of feed required, in addition to the maintenance requirement, to produce a 2-ounce egg. A value as high

as approximately 0.14 pound has been reported. The writer found the quantity to be 0.0888 pound of feed. Samuel Brody and co-workers at the Missouri Agricultural Experiment Station (Uni. Mo. Agr. Expt. Sta. Res. Bull. 278; 1938) found it to be 0.0865 pound of feed. The agreement between these two values is very close, and so either one may be used with a considerable degree of confidence. This is especially true in view of the fact that the writer obtained his value when working with 3.5-pound White Leghorn chickens and Brody and his associates obtained their value when working with chickens (both White Leghorns and Rhode Island Reds) that had an average live weight of about 4.75 pounds.

On the basis that the daily maintenance requirement of a 3.5-pound chicken is 0.14 pound of feed, and the quantity of feed required, in addition to the maintenance requirement, to produce a 2-ounce egg is 0.0888

Table 5. Estimates of the total feed required by chickens of different live weights for maintenance and the production of 0, 100, 150, 200, 250, and 300 eggs, respectively, per year.

Average live weight	Average total feed required per chicken per year for maintenance and the production of the indicated number of eggs					
	0 eggs	100 eggs	150 eggs	200 eggs	250 eggs	300 eggs
Pounds	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
2.0	34.1	43.0	47.4	51.9	56.3	60 7
2.5	40 0	48 9	53.3	57.7	62 2	66 6
3.0	45.7	54 5	59.0	63.4	67.9	72.3
3.5	51 1	60 0	64 4	68.9	73.3	7 77
4.0	56.3	65 2	69.7	74.1	78 5	83 0
4.5	61.4	70.3	74.7	79.2	83.6	88.0
5.0	66 3	75 2	79.6	84.1	88.5	92.9
5.5	71.1	80.0	84.4	88.8	93.3	97 9
6.0	75.7	84.6	89.1	93.5	97 9	102.4
6.5	80.3	89.3	93.6	98.1	102 5	106.9
7.0	84.8	93.6	98.1	102.5	107.0	111.4

pound, table 5 was set up. It shows the quantity of feed required per year for maintenance by chickens of selected live weights from 2 to 7 pounds and the total quantity of feed required by those chickens to produce 100 to 300 eggs per year.

As the preceding discussion and the estimates in table 5 indicate, a more or less fixed quantity of feed is required per day for the maintenance of a laying chicken of given live weight, no matter what its rate of egg production may be. Moreover, the quantity of feed required for making an egg is always less than the maintenance requirement, at least in chickens that

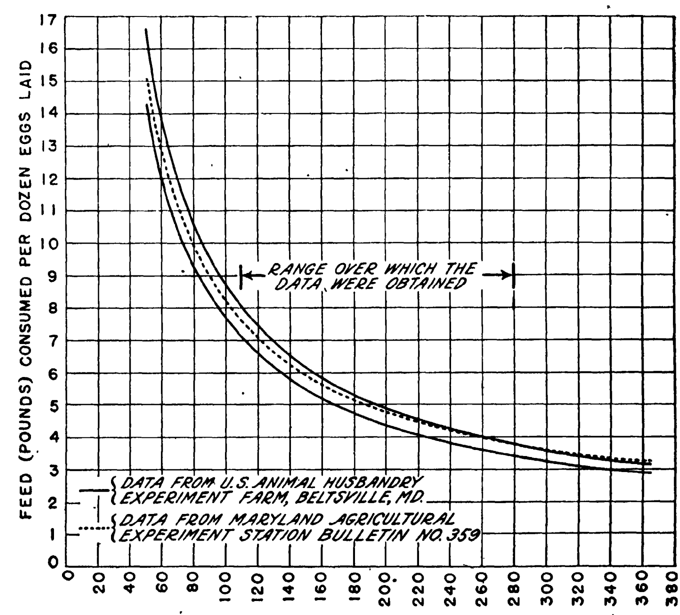

Fig. 3. The relationship between the quantity of feed consumed per dozen eggs and the average number of eggs laid per pullet per year. (Data obtained in different years from two different lots of White Leghorn pullets at the Beltsville Research Center, Beltsville, Maryland, and from Md. Agr. Expt. Sta. Bull. 359; 1934.)

weigh 2 pounds or more. Hence, it follows that the total quantity of feed required to produce an egg is much less when the average production of a flock is high than when it is low. It also follows, that the efficiency of egg production, that is, the number of eggs produced per pound of feed, increases as egg production increases.

The relationship between the quantity of feed consumed per dozen eggs and the average annual egg production is shown in figure 3, in which the feed consumed per dozen eggs is plotted against the average number of eggs laid per chicken per year. According to these curves, a White Leghorn pullet will consume between 7.7 and 8.7 pounds of feed per dozen eggs, if she lays 100 eggs per year, but only 4.4 to 4.9 pounds, if she lays 200 eggs. This clearly demonstrates the importance of having chickens that can be depended on to produce a large number of eggs per year.

The relationship between the efficiency of egg production and the average number of eggs laid per year is shown in figure 4 for White Leghorn pullets and hens and Rhode Island Red pullets and hens. This figure shows very definitely that chickens of the heavier breeds lay fewer eggs per pound of feed than do chickens of the lighter breeds; also, it shows that pullets lay more eggs per pound of feed than do hens of the same breed. Notwithstanding, it must be recognized that different strains of the same breed may be appreciably different in their ability to utilize feed for egg production, as is indicated by the three curves in figure 3.

Figure 5 shows how the average quantity of feed consumed per bird, per year, depends on the average percentage egg production. Curves are given for Rhode Island Red pullets and yearling hens and for White Leghorn pullets and yearling hens. The quantities of

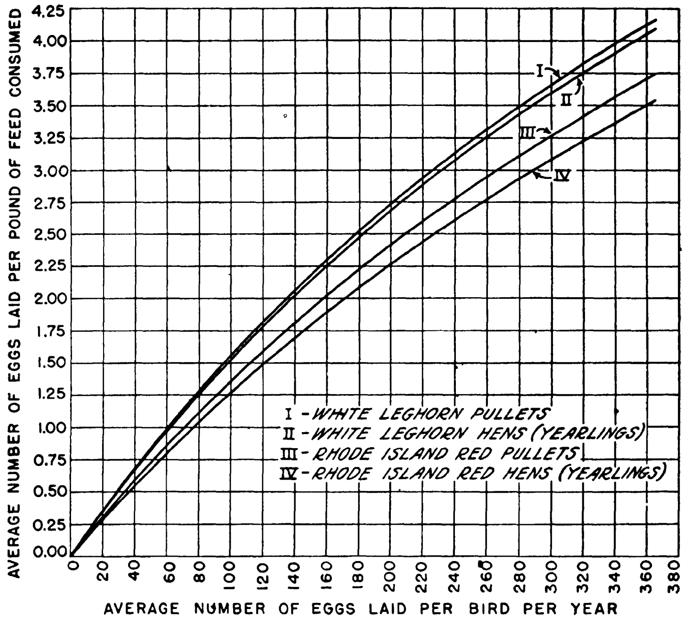

Fig. 4. The relationship between the number of eggs laid per pound of feed consumed and the average number of eggs laid per chicken per year. (Data from the Beltsville Research Center, Beltsville, Maryland.)

feed indicated for a given percentage egg production are only approximate because they depend to considerable extent on the average live weight of the chickens. In general, the heavier strains of both breeds will require somewhat more feed than the lighter strains.

To obtain and maintain a high rate of egg production it is necessary to maintain feed consumption at a correspondingly high level. Of course, a chicken can—and often does—produce eggs at a fairly high rate even if it does not receive enough feed to maintain its live weight, but it can do so for only a comparatively short time.

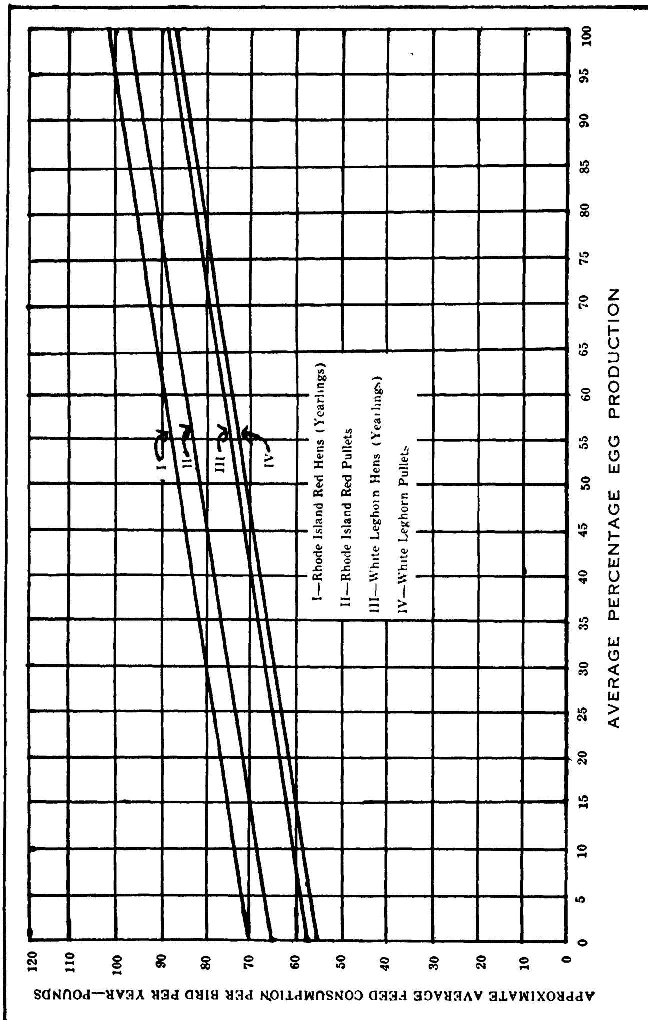

Fig. 5. The relationship between feed consumption and egg production in pullets and yearlings of two breeds of chickens.

The importance of the level of feed intake in egg production was very well demonstrated by Burt W. Heywang of the U.S.D.A. Southwest Poultry Experiment Station, Glendale, Arizona, in experiments he conducted in 1935 and 1936. In one of the experiments, he allowed two groups of chickens to eat all the feed they wanted for a period of 12 months but restricted the feed intake of two other groups to 87.5 per cent of the quantity consumed by the first two groups and restricted the feed intake of still another two groups to 75 per cent of the quantity consumed by the first two groups. He found that a reduction of 12.5 per cent in the feed intake caused an average decrease of about 32.5 per cent in the egg production and that a reduction of 25 per cent caused an average decrease of about 53.7 per cent.

Table 5 also illustrates the importance of the level of feed intake in egg production. For example, it indicates that if a typical 4-pound White Leghorn pullet consumes 74 pounds of feed per year, it should produce about 200 eggs; and if it consumes only 65 pounds of feed per year, it should produce only about 100 eggs.

NUTRITION AND REPRODUCTION

Reproduction in the chicken is different in several ways from reproduction in the other farm animals. It is much more rapid, the embryo develops outside the body, and the food of the young is not prepared within the body of the mother. In the other farm animals the development of the embryo from its inception to its birth is influenced by the contemporary feed supply of the mother. In the chicken, as in all poultry, the feed supply of the developing embryo is fixed within a relatively short time after the egg is fertilized, and thereafter until hatching the development of the embryo is independent of the contemporary feed supply of the mother. Once a fertile egg is laid, the nutritional fate of the contained embryo is fixed, except insofar as it may be influenced by the egg's physical environment. Nevertheless, diet may affect reproduction just as markedly in chickens and other poultry as in cattle, sheep, and swine.

Three ways in which diet may affect reproduction in the chicken may be considered. (1) It may affect the quantity and fertilizing capacity of the sperm produced by the males and thereby affect the number of eggs fertilized; (2) it may affect the egg production of the females; and (3) it may affect the composition of the eggs and thus, in turn, the hatchability of those that are fertile.

Effect of the Diet of the Males

There is very little definite information about the effect of the diet of male chickens on their ability to produce sperm or on the fertilizing capacity of their sperm. Because a deficiency of vitamins A and E, either

one or both, eventually leads to a failure of sperm production in the rat, it has been assumed that the same is probably true of other species. However, the writer has kept adult male chickens for more than 6 months on a diet that contained only about 10 International Units of vitamin A per 100 grams of feed—that is, about 6 to 10 per cent of the minimum requirement of actively growing chicks—without observing any decrease in their sperm production. Similar results were obtained when a diet rendered deficient in vitamin E by treatment with a solution of ferric chloride in ether was fed for 5 months. Furthermore, other workers have found that male chickens can be kept on a diet deficient in vitamin E for at least a year, and in some cases for as long as 2 years, without losing their ability to fertilize. Thus it may be concluded that, although male chickens may eventually become sterile if kept on diets that are markedly deficient in either vitamin A or E or in both, they are able to subsist for a rather long time on such diets without losing their ability to fertilize.

It has been claimed that when male chickens are fed a diet in which the protein is derived from plant sources only, they mate less frequently than when their diet contains some animal protein. Also, it has been reported that in one experiment the feeding of silage to male chickens tended to increase their sperm production. In both cases the experimental technique appears to have been faulty and incapable of yielding results from which reliable conclusions could be drawn.

There is no acceptable experimental evidence that the sperm production or fertilizing capacity of healthy male chickens can be increased by feeding special diets. On the other hand, the writer and W. H. Burrows, a former associate at the Beltsville Research Center, found that the feeding of desiccated thyroid gland

causes a steady and fairly rapid decrease in semen production. They found, also, that the addition of as little as 0.5 per cent of a certain sample of cold-pressed wheat germ oil to the diet caused a marked decrease in semen production.

Effect of Diet on Egg Production

There is an abundance of evidence that egg production is affected by diet. According to this evidence, a marked deficiency of any one or more of the following-listed nutrients causes a reduction or even cessation of egg production: Calcium, manganese, protein, vitamin A, vitamin D, riboflavin, and choline. It is not unlikely that there are still other nutrients, deficiencies of which have an adverse effect on egg production.

If a chicken does not consume enough calcium to permit it to make reasonably good eggshells, egg production decreases; and if the deficiency is sufficiently marked, egg production ceases. It is of more than passing interest, that if a chicken's intake of calcium is only partially deficient, the weight and strength of the shells of the eggs is not appreciably affected, but the rate of egg production is reduced. Thin-shelled eggs are ordinarily not a result of a deficiency of calcium, but are a result of other causes, such as a deficiency of vitamin D, expulsion of the egg before the complete shell has been formed, and a diseased condition of the oviduct.

A deficiency of manganese appears to reduce egg production. At least, it has been reported that egg production is increased appreciably when a small quantity of manganese is added to diets having a rather low content of this mineral element.

Egg production may be affected by both the quantity and quality of the protein in the diet. Only a few eggs are produced when the level of protein intake is

reduced below approximately 10 per cent of the diet. On the other hand, egg production cannot be increased appreciably by increasing the quantity of protein in the diet above 16 to 17 per cent, if the protein is of good quality. If the protein is of very poor quality, however, even as much as 16 to 17 per cent in the diet may not support good egg production.

Chickens often continue to produce eggs on diets that are partially deficient in vitamin A, vitamin D, riboflavin, or choline; even a fairly high rate of egg production may be maintained for a time. If the deficiency is marked, however, egg production soon stops.

Effect of Diet on Egg Composition

It now is rather generally accepted that the composition of an egg is, to a certain extent, dependent on the diet of the chicken that laid it. The egg's content of virtually all the vitamins required by the chicken is influenced by the quantities of these vitamins in the feed. Also, the percentage of both fat and protein in an egg is affected to a limited extent by the ingredients of the chicken's diet. Moreover, it has been adequately demonstrated that the composition of the fat in the egg's yolk is very readily influenced by the composition of the fat in the feed. Although no one, as yet, has been able to demonstrate that the composition of the proteins in an egg can be influenced by diet, it is not improbable that such a demonstration can be made as soon as sufficiently accurate methods of determining the amino acids are developed and applied.

The quantities of many elements and compounds in eggs, both regular and casual components, may be influenced by diet. In some instances, the quantity of a given element or compound may be influenced by the quantity of the element or compound, itself, in the feed or it may be influenced by the relative quantity of some

other element or compound in the feed. For example, eggs of a high or a low content of iodine may be produced at will by controlling the quantity of iodine in the feed. If the quantities of vitamin A and vitamin E in the diet are carefully adjusted, it is possible to increase the vitamin A content of the eggs that are produced by simply increasing the content of vitamin E in the diet. Again, if the quantity of vitamin D in the diet is extremely low, the eggs will contain appreciably less calcium and phosphorus than if the diet had contained an adequate quantity of vitamin D. Eggs of a low content of calcium or phosphorus, or of both, may also be obtained by limiting the quantities of these two elements in the diet.

The manganese content of eggs is markedly affected by the manganese content of the feed. The feeding of cod-liver oil has been reported to increase the percentage of both copper and iron in the yolk of eggs; and it has been reported that sunshine has essentially the same effect as cod-liver oil. There is conflicting evidence regarding the possibility of affecting the iron content of eggs by including iron compounds in the diet. Still other elements and compounds when ingested with the feed are later found in the eggs that are produced. Among these elements and compounds are: selenium, bromine, benzoic acid, certain alcohol-soluble dyes, and several of the plant pigments, such as xanthophyll, zeaxanthin, cryptoxanthin, and capsanthin.

Effect of Diet on Hatchability

In view of the fact that the composition of all eggs is not the same and that the composition of the diet determines to some extent the composition of the egg, it is logical to assume that hatchability can be very markedly affected by diet. That such is the case, has been demonstrated many times. As a matter of fact,

hatchability is a much more sensitive indicator of the adequacy of a given diet than is egg production. That is to say, it is possible to formulate two or more diets on which the egg production will be essentially the same but the hatchability widely different. Among the dietary factors that have been found to affect hatchability are: the quantity and quality of the protein, the quantities of several of the mineral elements, and the quantities of several of the vitamins.

Protein and hatchability.—When the usual feedstuffs are used, no improvement in hatchability normally results from increasing the protein in the total feed above 15 per cent. If the protein in the total feed falls below 12 per cent, however, there is a tendency for the hatchability to decrease.

Almost nothing is known about what constitutes good quality in protein from the standpoint of hatchability. It has been observed, however, that some protein supplements tend to improve hatchability or to maintain good hatchability. Likewise, it has been observed that some protein supplements tend to depress hatchability.

Certain animal-protein supplements appear to contain a factor or factors—referred to as the "animal-protein factor"—that is necessary for maintaining high hatchability. Thus, a small quantity of fish meal, dried milk, liver meal, or meat scrap often has a beneficial effect on hatchability that cannot be explained by the amino acid content of the product used. Nor, for that matter, can it be explained by the product's content of any of the currently accepted vitamins.

Among the protein supplements that have been observed to have a detrimental effect on hatchability are liquid stick (from the steam rendering of fatty animal material), blood meal, some lots of tankage, cottonseed meal having a high content of gossypol, and soybean

meal. In the case of soybean meal, however, the depressing effect on hatchability can be nullified by including a small quantity of fish meal, fish solubles, or meat scrap in the diet. The writer knows of no work that indicates that the depressing effect of liquid stick, blood meal, and some lots of tankage can be overcome in the same way.

Minerals and hatchability.—It has been demonstrated many times that an adequate dietary supply of calcium is necessary for good hatchability. Any pronounced restriction of calcium intake is soon followed by a corresponding reduction in hatchability. Moreover, the withdrawal of the calcium supplement often causes the percentage hatchability to fall to zero. Also, it has been found that too much calcium adversely affects hatchability. However, whether or not a given quantity of calcium is excessive depends on the phosphorus content of the feed. As the phosphorus content of the total feed is increased, the tolerance as well as the need for calcium is increased.

Manganese, also, is necessary for good hatchability and for the formation of good egg shells as well. If the feed of chickens is markedly deficient in manganese, the embryos in the resulting eggs do not develop normally.

Iodine is one of the six essential trace mineral elements, but it has not been clearly demonstrated that it is necessary for maintaining good hatchability. It is probable that only a marked deficiency of iodine would decrease hatchability, if the diet were adequate in every other way.

A marked deficiency of salt has been found to reduce both egg production and hatchability and adversely affect the general health of the chickens.

Selenium is one mineral element that is known to have a harmful effect on embryonic development and

hatchability. If the total feed contains even as little as 15 parts per million of selenium, the percentage hatchability tends, after a period of a few weeks, to decrease to zero.

Vitamins and hatchability.—Among the vitamins known to be necessary for good hatchability are vitamin A, vitamin D, vitamin E, riboflavin, pantothenic acid, pyridoxine, biotin, folic acid, the animal-protein factor, and, probably, choline. Apparently, vitamin B_1 is not required for good hatchability, but chicks from hens on diets extremely low in vitamin B_1 show symptoms of polyneuritis soon after hatching and rarely survive more than 24 hours. Whether or not vitamin C is required for hatchability is not known, but it is known that the chicken is able to synthesize this vitamin. Moreover, although there is no vitamin C in unincubated eggs, it is formed in eggs that have been incubated a few days. As yet, there is no good evidence that vitamin K, inositol, glucuronic acid, vitamin P, para-aminobenzoic acid, niacin, and the essential fat acids are necessary for good hatchability.

Fat and carbohydrate in relation to hatchability.—Comparatively few studies have been made of the effect of fat on hatchability. In those that have been made, it was shown that the addition of as much as 8 per cent of corn oil, 3.6 per cent of soybean oil, or 7 per cent of peanut oil did not adversely affect hatchability, but that 3.6 per cent of crude cottonseed oil markedly reduced hatchability although highly refined cottonseed oil had no effect.

Although, apparently, no studies have been made of the effect of typical carbohydrates on hatchability, a number of workers have studied the effects of the several grains in otherwise similar diets. From the standpoint of hatchability, wheat appears to be the best of the four common grains, but its advantage is

very slight—perhaps, non-existent—when the grains are singly included in properly balanced diets.

Hatchability and adaptation to diet.—The writer and his former associates at the Beltsville Reseach Center studied the hatchability of the eggs of pullets that received diets in which the protein was derived solely from (1) wheat middlings, (2) corn and corn gluten meal, and (3) soybean meal. Some of the pullets were fed these diets from the time they were hatched and some only after they had reached sexual maturity on a well-balanced diet. The hatchability of the eggs from the pullets that were raised on these special diets was significantly better than that of the eggs from the pullets that were raised on the well-balanced diet. These findings indicate that, of the chickens raised on the diets in which the protein was obtained from a single-plant source, those that were unable to utilize such restricted sources of protein died before they reached maturity. In effect, however, the chickens that were raised on the special diets became adapted to them and were able to reproduce better on them than were the chickens that were raised on the well-balanced diet.

NUTRIENT REQUIREMENTS AND ALLOWANCES

It is necessary to distinguish between nutrient requirement and nutrient allowance. The *requirement* of an animal for a given nutrient is the minimum quantity of that nutrient, when all other nutrients are supplied in adequate quantities, that will maintain normal growth and reproduction and, at the same time, prevent the development of symptoms of nutritional deficiency. When defined in this way, the requirement for a given nutrient is the same as the "minimum requirement" for that nutrient. The *allowance* of a given nutrient is that quantity of the nutrient that is given to the animal.

If all nutrients were stable, if the composition of all feedstuffs were constant, and if environmental conditions had no effect on the nutrient requirements of an animal, then the nutrient allowances could be the same as the nutrient requirements. Some nutrients are practically stable, but others are comparatively instable. The composition of feedstuffs is not constant; for example, some lots of yellow corn may contain as much as 4,000 I.U. of vitamin A activity per pound, whereas others may contain as little as a few hundred I.U.; likewise, some lots of yellow corn may contain as much as 11 per cent of protein, whereas other lots may contain as little as 7 or 8 per cent. Moreover, environmental conditions do effect certain nutrient requirements; for example, animals that have access to sunshine have a lower dietary requirement of vitamin D than those that do not.

Accordingly, in setting up nutrient allowances for the chicken—or any other animal—it is necessary to

take into consideration the subjects discussed in the preceding paragraph. Also, it is necessary to give consideration to the purpose for which the chickens are to be fed: whether it be for growth, maintenance, egg production, hatchability, or fattening. In addition, economy must be considered.

In general, the diet should supply adequate quantities of protein, carbohydrates, fat, minerals, vitamins, and water for the purpose for which it is fed. If considerably larger quantities of protein, fat, and vitamins are supplied than are required, the chickens may be well nourished, but not economically nourished, because those three nutrients usually are the more expensive ones. In other words, it is not economical to force chickens to use protein and fat as sources of energy when the cheaper carbohydrates will serve the same purpose equally well, or even better; nor is it economical to supply one or more of the vitamins in gross excess of the chicken's requirements. Likewise, it is not economical to supply too small quantities of minerals and vitamins, and, thus, cause the chickens to use the protein in their feed less efficiently.

On the other hand, it is more economical to feed somewhat more protein and vitamins than may be required than it is to feed too little. This is true also of the mineral elements; but, in attempting to supply them in adequate quantities, there is likely to be a tendency to use too much because they are comparatively cheap. A large excess of the mineral elements in the diet should be carefully avoided.

The usual primary object in keeping chickens is to make as much profit as possible. Inasmuch as rapidly growing chickens tend to make more economical gains than those that grow slowly, and high egg production cannot long be maintained on a restricted level of feed intake, it has become a rather general practice to feed

both growing and laying stock as much feed as they will consume. Systems of rationing, that is, systems of restricting the feed intake to some predetermined level, generally have not proved to be popular or profitable. Accordingly, in setting up nutrient allowances for the several classes of chickens, particular attention should be given to the problem of supplying protein, minerals, and vitamins in quantities that will sustain a rapid rate of growth or of egg production. No attempt need be made to control directly the intake of carbohydrate, and only in the case of chickens that are to be finished for market need the fat intake be given any special consideration.

After nutrient allowances have been set up, there, quite naturally, arises the question: How can the poultryman use them? Ordinarily, a poultryman does not have the facilities for making chemical analyses and vitamin assays of the feedstuffs he uses. Furthermore such analyses and assays involve too great an expense for most poultrymen to incur. However, it is possible to use tables that give the average chemical composition and vitamin content. Such tables are given at the end of this book. It usually is better, however, to use the feed of a reputable manufacturer who has all the necessary facilities for producing dependable formula feeds.

It should be pointed out that "the necessary facilities for producing dependable formula feeds" include (1) the services of a thoroughly trained nutritionist who has, in addition to his knowledge of animal nutrition, a first-hand familiarity with, at least, the more commonly used feedstuffs, and (2) a laboratory equipped to make routine analyses and assays. The services of a thoroughly trained nutritionist are a primary requisite. A laboratory is highly desirable, but not absolutely essential. However, when a feed manu-

facturer does not have a laboratory, he should have his raw ingredients and his finished products checked, from time to time, by a dependable commercial laboratory.

Nutrient Allowances for Growing Chickens

Nature provides a concentrated supply of nutrients for the newly hatched chick within its own body. The unabsorbed yolk constitutes this supply. It is sufficient to maintain the chick for several days, but experience has shown that the best results are obtained if both water and feed are supplied when the chick is about one day old.

Protein.—Studies of the effect of the level of protein intake on growth have shown that the physiologically optimum percentage of protein in the diet of the growing chick is approximately 21 per cent, when the protein is of reasonably good quality. This level gives the best results at all live weights from hatching until growth is nearly completed. It has been observed, however, that if chicks are started and kept on a diet of lower protein content, e.g., 18 per cent, their rate of growth after they are 12 to 16 weeks old may be more rapid than that of chicks started and kept on a diet containing 21 per cent of protein. Nevertheless, the utilization of feed for growth is more efficient in actively growing chicks of the *same weight,* regardless of age, when the diet contains about 21 per cent of protein than when it contains appreciably less.

The apparent disagreement between the last two statements may be explained as follows: Chicks ordinarily grow more rapidly on a diet that contains 21 per cent of protein than on one that contains 18 per cent, when the protein in both diets is of the same quality. On any diet of fixed protein content the efficiency of feed utilization decreases as the live weight increases.

Hence, if two equal lots of chicks, of the same breed and strain and from the same hatch, are fed diets that contain 21 and 18 per cent of protein, respectively, the lot of chicks receiving the larger percentage of protein will grow more rapidly than the other lot and, as a consequence, the efficiency of feed utilization of the former will decrease more rapidly than that of the latter. By the time both lots are 16 weeks old, the rate of growth of the second lot may be definitely greater than that of the first lot. However, as the live weight of the second lot increases, the efficiency of feed utilization decreases at such a rate that, for *any given live weight* appreciably less than the mature weight, it is less than that of the first lot.

Although a diet containing about 21 per cent of protein is more efficiently utilized than one containing about 18 per cent, the latter diet may be more economical if its cost is sufficiently less than that of the former. In any case, it ordinarily is best to start with a well-balanced diet containing about 20 to 23 per cent of protein and then decrease the protein content gradually after the chicks are about 10 to 12 weeks old, *if the cost of the ensuing gain in weight is thereby reduced enough to warrant the change.* Frequently the cost of the gain is decreased enough to warrant the gradual lowering of the protein content until it is as low as 15 or 16 per cent *by the time the pullets are ready to lay.*

The data in table 6 may be used as an approximate guide in deciding which of two diets of different protein content will be the more economical to use. It is obvious, however, that the comparison will not be valid, unless both diets contain protein of essentially equal quality, or biological value. According to these data, if one diet contains 21 per cent of protein and sells for 80 dollars per ton and another diet contains 18 per cent of

protein and sells for 76 dollars per ton, the second one will be the more economical. This follows from the fact that the second diet costs only 95 per cent as much as the first but is 97.2 per cent as efficient. However, if

Table 6. Effect, in the male chicken, of the level of protein intake on the relative efficiency of the utilization of feed for growth, the relative maximum live weight attained, the relative quantity of feed required for attaining the maximum live weight, and on the relative length of time required to attain the maximum live weight.

Level of protein intake as per cent of the total feed consumed	Relative average efficiency of the utilization of feed for growth	Relative maximum live weight[1] attained	Relative quantity of feed required for attaining the maximum live weight [1]	Relative length of time required to attain the maximum live weight[1]
Per cent	Per cent	Per cent	Per cent	Per cent
13	67.7	97.6	144.1	119.9
14	80.6	97.9	121.3	111.7
15	87.3	98.2	112.5	107.8
16	91.5	98.6	107.7	104.6
17	94.6	98.9	104.6	102.6
18	97.2	99.2	102.1	101.5
19	98.7	99.5	100.7	101.0
20	99.7	99.8	100.1	100.5
21	100.0	100.0	100.0	100.0
22	97.9	100.2	102.3	99.7
23	94.3	100.4	106.4	99.5
24	90.2	100.5	111.4	99.4
25	85.6	100.6	117.5	99.2

[1]This refers to the maximum live weight that is attained when the birds are fully grown.

the second diet sells for 78 dollars per ton, it is slightly less economical than the first because it costs 97.5 per cent as much but is only 97.2 per cent as efficient.

Since 1941, the idea of using a high-protein all-mash starting feed for about two weeks and then shifting to an all-mash growing feed or to a growing mash with which grain is to be fed has received considerable attention. These high-protein starting feeds contain 28

to 32 per cent of protein; they also contain more of the vitamins, especially vitamin A, vitamin D, riboflavin, and pantothenic acid.

The high-protein starting feed has the advantage that it stimulates the early growth of the chickens. The result is that the chicks tend to be heavier at all ages up to 11 or 12 weeks than chicks that are started on feeds that contain 20 to 23 per cent of protein. As is well known, it takes less feed to produce a given gain of weight during the first two weeks—or two months—than it does to produce the same gain in any subsequent two weeks—or two months. Also, it may be pointed out that the cost of using a high-protein starting feed for the first two weeks is small. New Hampshires and Rhode Island Reds, for example, usually consume only about 0.5 to 0.6 pound of feed per chick during the first two weeks after hatching.

To the raiser of broilers, the early stimulation of growth that results from feeding a high-protein starting feed for the first two weeks is well worth the very small cost it takes to obtain it. To the poultryman who is not raising chickens for meat and is not interested primarily in obtaining rapid growth, the more common starting feeds that contain 20 to 23 per cent of protein are likely to be preferable. A poultryman's actual preference will depend, in most instances, on the experience he has had. Some poultrymen like the idea of feeding the same starting-and-growing feed until it is time to begin feeding a laying feed. Other poultrymen like the idea of using a starting feed for a time and then changing to a growing feed.

Amino acids.—The greater part of our knowledge of the amino acid requirements of the growing chicken has resulted from the studies of Dr. H. J. Almquist, formerly Associate Professor of Poultry Husbandry in the College of Agriculture of the University of Cali-

fornia, Berkeley, California, and now (at this writing) Director of Research, the F. E. Booth Company, Inc., San Francisco, California. As he has pointed out, "The protein requirement of an animal is actually a requirement for the amino acids which a protein contains."

Inasmuch as the quality, or biological value, of a protein depends on the amino acids it contains—which ones and how much of each—it is not enough to specify that a given feed for growing chickens contain a certain quantity of protein. It is desirable to specify that the feed, regardless of whether its protein content is 20 or 23 per cent, contain certain minimum quantities of several of the amino acids. These minimum quantities are approximately as follows, when expressed as per cent of the total feed consumed:

Amino acid	Quantity in total feed	Amino acid	Quantity in total feed
	Per cent		Per cent
Arginine	1.0	Leucine	1.4
Lysine	1.0	Phenylalanine	.95
Methionine	.5[1]	Threonine	.7
Cystine	.3[1]	Valine	.8[4]
Tryptophane	.25[2]	Histidine	.35
Glycine	.8	Tyrosine	.75[5]
Isoleucine	.6[3]		

[1]The cystine may be less than 0.3%; but if it is appreciably less than 0.3%, the sum of the menthionine and cystine should not be less than 0.85%.

[2]Must be l-tryptophane or 0.5% of dl-tryptophane.

[3]Must be l-isoleucine; d-isoleucine does not replace l-isoleucine in growth.

[4]Must be l-valine; d-valine does not replace l-valine in growth.

[5]Tyrosine may be replaced, wholly or in part, by phenylalanine.

In most feed mixtures for growing chickens there usually is as much or more isoleucine, leucine, phenylalanine, threonine, valine, and histidine than the quantities just listed. Accordingly, it usually is necessary to give special consideration to only arginine, lysine, methionine, cystine, tryptophane, and glycine.

One point that should be kept in mind is that, if appreciably less than the listed quantity of any one of these amino acids (except glycine, cystine, and tyrosine) is present in the feed of growing chickens, nothing is gained by having the full quantities of all the others. That is to say: any one of the required amino acids may be a limiting factor in obtaining the maximum gain from a given quantity of feed. Exception is made of glycine, cystine, and tyrosine because the chick can make glycine from creatine and from acetates, and can use methionine in place of cystine, and phenylalanine in place of tyrosine.

Minerals.—In formulating feed mixtures for growing chicks, attention should be given to the fact that the phosphorus in feedstuffs is present in several different forms: inorganic phosphates, phytin, phospholipids, and phosphoproteins; and that the phosphorus in phytin is poorly available. The greater part of the phosphorus in feedstuffs of plant origin is present in the form of phytin and inorganic phosphates; comparatively little is present in other forms, such as phospholipids and phosphoproteins. In the cereal grains as much as 60 per cent of the total phosphorus may be in the form of phytin; in bran and middlings, as much as 90 per cent; and in the oil-seed meals, about 75 per cent. On the other hand, in products of animal origin, such as bone meal, fish meal, meat scrap, dried buttermilk, dried skim milk, and dried whey, nearly all the phosphorus is present in the form of inorganic phosphates.

Calcium and phosphorus.—In the earlier studies of the calcium and phosphorus requirements of growing chickens, allowance was not made for the fact that phytin phosphorus is poorly available and that the greater part of the phosphorus in grains and seeds and their byproducts is present in the form of phytin. Ac-

cording to those earlier studies, the calcium and phosphorus requirements of very young chicks are met by a diet that contains about 0.7 to 0.75 per cent of calcium and about 0.4 to 0.5 per cent of phosphorus. The usually recommended allowances were about 1.0 to 1.1 per cent of calcium and 0.6 to 0.7 per cent of phosphorus. Those allowances were, and still are, satisfactory if the feed contains 0.2 to 0.3 per cent of inorganic phosphorus. Ordinarily, a feed mixture for growing chickens will not contain much more than 0.4 to 0.5 per cent phytin phosphorus.

Merely because phytin phosphorus is poorly available to the growing chicken, it should not be assumed that none of it is used. Some phytin phosphorus is used; the relative quantity that is used depends on the other ingredients of the diet, and particularly on the kind of vitamin D. If the vitamin D is from D-activated animal sterol, more phytin phosphorus may be used than if the vitamin D is from fish and fish-liver oils.

Analyses of the entire carcasses of growing chicks at different ages show that, for each part by weight of phosphorus that is retained from the feed, about 1.6 parts of calcium are also retained. This ratio—the calcium-phosphorus retention ratio—varies from about 1.4:1, when the first feed is consumed, to about 1.8:1, when the chicks are nearly grown. In other words, the average calcium-phosphorus retention ratio is about 1.6:1, or slightly more. Accordingly, if due allowance is made for the fact that about 0.4 per cent of the feed is phytin phosphorus and only a portion of this phosphorus is utilized, a suitable dietary calcium-phosphorus ratio appears to be between 1:1 and 1.2:1. If all the phosphorus were present as inorganic phosphorus, a suitable dietary calcium-phosphorus ratio would be between 1.6:1 and 1.8:1. In practical feed mixtures for growing chickens the calcium-phosphorus

ratio may vary from 1:1 to 1.6:1, depending on the total quantity of phosphorus and the ratio of phytin phosphorus to inorganic phosphorus. Experience has shown that a calcium-phosphorus ratio of 1.6:1 is generally satisfactory, but that narrower ratios may be used.

A satisfactory allowance of phosphorus in the total feed of growing chickens is 0.6 to 0.9 per cent; the corresponding allowance of calcium is from 1.0 to 1.5 per cent.

Sodium and chlorine.—All classes of chickens require a small quantity of sodium chloride (common salt) in their diet. The quantity to include in the diet depends to a certain extent on the other ingredients. Virtually all feedstuffs contain some sodium and chlorine; and certain ones tend to contain appreciably more than others. The actual requirement of the chicken for sodium chloride is not known, but observation and experience indicate that it most likely is not in excess of 0.5 per cent of the total feed.

Inasmuch as the total feed, exclusive of the added salt it contains, usually has a sodium chloride content of only 0.15 to 0.3 per cent, it is desirable that the quantity of added salt be about 0.25 to 0.40 per cent. In those instances in which the total feed contains large quantities of meat scrap, fish meal, or both, it may not be necessary or desirable to add even as much as 0.25 per cent of salt. However, in those instances in which the total feed contains no meat scrap or fish meal, it may be desirable to add as much as 0.4 per cent of salt.

A satisfactory allowance of *added* salt in the total feed of growing chickens is 0.30 per cent (0.25 to 0.40%, depending on the sodium chloride content of the other ingredients of the feed).

Manganese.—It is generally known that manganese is very effective in the prevention of perosis under practical conditions. The manganese requirement of the growing chicken is about 50 parts per million parts of feed, that is, 50 PPM. Typical feed mixtures for growing chickens contain 30 to 50 PPM. Accordingly, it very seldom is necessary to add more than 20 PPM of manganese to the total feed of growing chickens. However, it is a common practice to add 4 ounces of feeding grade manganese sulphate (65% $MnSO_4$) to each ton of all-mash feed. This quantity of manganese sulphate adds 30 PPM of manganese to the feed, or 50 per cent more than need be added. Except in unusual cases, it is not necessary to add more than 2⅔ ounces of feeding grade manganese sulphate to a ton of all-mash feed, or more than 5⅓ ounces to a ton of mash with which an approximately equal weight of grain is to be fed.

Iodine.—There are but few quantitative data on the iodine requirement of the growing chicken. Those few data indicate that the iodine requirement is between 2 and 5 PPM. Inasmuch as typical feed mixtures for growing chickens rarely contain as much as 1 PPM of iodine before an iodine supplement is added—and many such feed mixtures contain even less than 0.3 PPM—it is desirable to add at least 2 PPM, and possibly as much as 4.5 PPM.

It may be pointed out that iodized salt is not satisfactory for adding as much as 2 PPM of iodine to a feed mixture. Salt normally is included in all-mash feeds at a level not greater than 0.5 per cent, and in mashes with which grain is to be fed it normally is included at a level not greater than 1.0 per cent. Iodized salt contains only 0.007 per cent (or 70 PPM) of iodine. Hence, 0.5 per cent of iodized salt increases the iodine content of a feed mixture by only 0.35 PPM, and 1.0 per cent

increases it by only 0.7 PPM. To be an adequate source of iodine in poultry feeds, an iodized salt should contain not less than 0.04 per cent (or 400 PPM) of iodine.

Iron.—The iron requirement of the growing chicken probably is between 20 and 30 PPM. Inasmuch as the iron content of many of the ingredients of feed mixtures for growing chickens is in excess of 30 PPM, the likelihood of an iron deficiency is not great. For example, the iron content of corn is 30 to 45 PPM; that of wheat, 40 to 110 PPM*; that of oats 50 to 220 PPM*; that of barley 40 to 150*; bran averages about 75 PPM; soybean meal averages about 30 PPM, and feed mixtures to which no iron supplement has been added usually contain 25 to 100 PPM.

Copper.—The copper requirement of the growing chicken probably is between 2 and 3 PPM. There are only a few data on the copper content of feedstuffs, and so it is difficult to judge what the likelihood of a copper deficiency is. In any case, the copper content of alfalfa meal usually is slightly in excess of 10 PPM; that of corn is about 4.5 PPM; that of wheat and barley, about 7.5 PPM; and that of oats, about 8 PPM.

Cobalt.—It is not known whether or not cobalt is essential for the chicken. Cobalt deficiency has been demonstrated only in ruminants. However, cobalt is a constituent of vitamin B_{12}, (*added in proof*) and it has been found that small quantities of cobalt will increase the number of red blood cells in the rat and in the duck.

Potassium.—The growing chicken's requirement of potassium has been reported to be about 0.8-1.0 gram per pound of feed or about 0.17-0.22 per cent. Comparatively few of the ingredients used in feeding poultry contain as little potassium as 0.22 per cent. Average values for the potassium content of typical feedstuffs

*The higher value probably is unusual. The average value usually is much nearer the lower value than the higher value.

are about as follows: Alfalfa meal, 2.0 per cent; barley, 0.48 per cent; dried buttermilk, 1.7 per cent; fish meal, 0.6 per cent; meat scrap, 0.55 per cent; oats, 0.45 per cent; soybean meal, 2.0 per cent; wheat 0.5 per cent; wheat bran 1.25 per cent; and wheat middlings 1.1 per cent. Accordingly, a dietary deficiency of potassium is extremely unlikely—a considerable excess above actual requirements is far more likely. Nothwithstanding, potassium chloride has been used, apparently with success, in treating "blue comb," or "pullet disease." Undoubtedly, the efficacy (?) of potassium chloride is dependent on a therapeutic effect rather than a nutritional effect.

Magnesium.—The requirement of the growing chicken for magnesium has been reported to be 0.04 per cent. None of the ingredients commonly used in feeding poultry contain less than this quantity and many of them contain from 2 or 3 to 25 times as much. For example, bone meal contains about 0.85 per cent; corn, 0.12 per cent; fish meal, 0.2 to 0.3 per cent; meat scrap, about 0.17 per cent; bran, about 0.53 per cent; and middlings, about 0.37 per cent. As a matter of fact, many good chick starters contain from 0.25 to 0.5 per cent.

Sulphur.—Reference is sometimes made to the sulphur requirement of an animal. Generally speaking, the chicken and other non-ruminants can use only very small quantities of inorganic sulphur. The greater part of this element used by the chicken must be supplied in organic form, that is, in the form of methionine, or methionine and cystine. Accordingly, nothing of nutritional value is gained by adding elemental sulphur or one of the sulphates to the feed, that is to say, by adding an inorganic source of sulphur.

Zinc and silicon.—Undoubtedly, the chicken requires both zinc and silicon. The necessary quantity of

zinc is so small, and the distribution of zinc and silicon is so general, that a deficiency of either element is extremely unlikely under practical conditions.

Vitamins.—In formulating diets for growing chickens, special attention should be given to the matter of supplying adequate quantities of vitamin A, vitamin D, and riboflavin. It is well, also, to give some attention to the content of pantothenic acid and choline in such diets. Typical diets for growing chicks usually contain fully adequate quantities of vitamin E, vitamin K, inositol, glucuronic acid, thiamine, pyridoxine, para-aminobenzoic acid, niacin, biotin, folic acid, and the essential fat acids.

Vitamin A.—A satisfactory allowance of vitamin A activity is 2,000 I.U. per pound of feed. The actual requirement of young growing chickens (up to the age of 6 to 8 weeks) for vitamin A activity is between 700 and 800 I.U. per pound of feed. The requirement increases with age and, probably, is at least 1,200 I.U. per pound of feed by the time sexual maturity is reached or shortly before.

Vitamin D.—A satisfactory allowance of vitamin D is 180 A.O.A.C. chick units per pound of feed, but may poultrymen prefer to use as much as 270 A.O.A.C. chick units. The actual requirement of young growing chickens for vitamin D is between 70 and 90 A.O.A.C. chick units per pound of feed, but for certain levels of calcium and phosphorus intake it may be even less than 70 A.O.A.C. chick units. The requirement for vitamin D decreases with age until sexual maturity is reached. In the mature male chicken the actual requirement is comparatively low, but in the egg producing female it is considerably higher than in the young growing chick.

Riboflavin.—A satisfactory allowance of riboflavin is 1.7 milligrams per pound of feed. The requirement of riboflavin decreases rapidly with age, and so, an

allowance of 1.6 to 1.7 milligrams usually is fully adequate for the first eight weeks. After the eighth week, as little as 1.0 milligram of riboflavin per pound of feed appears to be enough.

Pantothenic acid.—A satisfactory allowance of pantothenic acid is 5 milligrams per pound of feed. The actual requirement of the growing chicken, however, probably is not in excess of 4 milligrams per pound of feed.

Choline.—A desirable allowance of choline for the growing chicken is 700 milligrams per pound of feed, but an allowance of about 600 milligrams is satisfactory. Choline has several functions in the chicken, some of which can be performed by methionine and betaine. Accordingly, both methionine and betaine are able to "spare" a limited quantity of choline. If none of the functions of choline were performed by methionine, betaine, and other choline-sparing compounds, the growing chicken's requirement for choline probably would be in excess of 700 milligrams per pound of feed.

Other vitamins.—The growing chicken's requirement for vitamin E is not known accurately; however, it probably is not less than 6 milligrams per pound of feed and a satisfactory allowance is 9 milligrams per pound.

According to the National Research Council ("Recommended Nutrient Allowances for Poultry," June, 1944), the vitamin K requirement of the growing chicken is 0.18 milligram per pound.

The requirements of the growing chick for some of the other vitamins appear to be approximately as follows:

Thiamine	0.7	milligrams per pound of feed
Pryridoxine	1.5	" " " " "
Niacin	7.0	" " " " "
Biotin	.045	" " " " "
Folic acid	.25	" " " " "

It should be noted, however, that the dietary niacin requirement is dependent on the quantity of tryptophane in the diet and that probably no pre-formed niacin is required if the diet supplies enough tryptophane.

Nutrient Allowances for Laying and Breeding Stock

The nutrient requirements of laying chickens are qualitatively the same as those of growing chickens; however, they are quantitatively different.

It has been demonstrated a number of times that it is possible to compound two or more diets on which the egg production will be practically the same but on which the hatchability will be very different. It has been found, however, that the eggs of chickens that lay a large number tend to hatch better than those of chickens that lay a small number. This suggests that it always is best to feed diets that will permit the chickens to produce eggs of high hatchability, because poor hatchability may be the result of a dietary deficiency too slight to decrease egg production but large enough to undermine the health of the chicken.

Protein.—Although the protein requirement of the laying chicken has been studied by many investigators, the optimum percentage of protein in the diet has not been determined accurately from the standpoints of physiological efficiency and financial economy. It is known, however, that an average egg that weights 56.7 grams (2 ounces) contains slightly more than 7 grams of protein of very high quality, or biological value. To produce such an egg, a chicken requires from 10.5 to 12.5 grams of digestible protein; and to supply this, 12.5 to 15 grams of feed protein of good quality is required.

Inasmuch as the chicken has a rather limited capacity for storing protein that can be used for making

eggs, the feed consumed each day should furnish not less than 12.5 grams of protein of good quality, if a constantly available supply thereof for making eggs is to be maintained. A 4-pound White Leghorn pullet that lays 200 eggs per year will consume, on the average, about 92 grams of feed per day, and a 5.5-pound Rhode Island Red pullet that lays the same number of eggs will consume, on the average, about 110 grams of feed per day. Accordingly, the feed of the White Leghorn pullet should contain between 13.5 and 16 per cent of protein of good quality, and the feed of the Rhode Island Red pullet should contain between 11.5 and 13.5 per cent.

It has been found that good egg production—200 eggs or more per year—may be obtained on diets containing 12 to 13 per cent of protein. Nevertheless, general experience indicates that a level of protein intake of 14 to 16 per cent usually is best. The lower level, 14 per cent, is satisfactory for chickens of the heavy breeds, but the higher level, 16 per cent, is preferable for chickens of the light breeds. Feeds intended for both light and heavy breeds should supply 15 to 16 per cent of protein—or even 17 per cent; that is, all-mash feeds should contain 15 to 17 per cent of protein, and mashes with which an equal quantity of grain is to be fed should contain not less than 20 to 23 per cent.

Amino acids.—Very little is known about the chicken's requirement of amino acids for egg production. However, on the basis of the known amino acid content of eggs, it may be estimated that for the production of one egg per day the feed consumed each day should supply the following approximate quantities of certain ones of the amino acids:

Amino acid	Quantity	Amino acid	Quantity
	Grams		Grams
Arginine	0.464	Leucine	0.657
Lysine	0.422	Phenylalanine	0.428
Methionine	0.343	Threonine	0.328
Cystine	0.179	Valine	0.521
Tryptophane	0.107	Histidine	0.150
Glycine	0.171	Tyrosine	0.336
Isoleucine	0.571		

When a 4-pound White Leghorn pullet lays at the rate of an egg per day, she requires about 110 grams of feed per day; and when a 5.5-pound Rhode Island Red pullet lays at the same rate, she requires about 129 grams. If a diet is formulated to take care of the amino acid requirements of White Leghorn pullets, it will be more than adequate for pullets of the heavier breeds because the latter's feed consumption is larger. On the basis that 110 grams of feed are required to supply the amino acids for making an egg and that 85 per cent of the protein consumed is digested and becomes available, the amino acid content of the feed should be not less than the following-listed percentages:

Amino acid	Quantity in total feed	Amino acid	Quantity in total feed
	Per cent		Per cent
Arginine	0.50	Leucine	0.70
Lysine	0.45	Phenylalanine	0.46
Methionine	0.37	Threonine	0.35
Cystine	0.19[1]	Valine	0.56
Tryptophane	0.12	Histidine	0.16
Glycine	0.18	Tyrosine	0.36[2]
Isoleucine	0.61		

[1]Cystine may be replaced, wholly or in part, by menthionine.
[2]Tryosine may be replaced, wholly or in part, by phenylalanine.

These estimates of the amino acid requirements for egg production furnish an explanation why the laying hen can continue to produce eggs at a good rate on diets, the protein of which is derived solely from the

cereal grains and the oil-seed meals. Although the cereal grains, as a class, do not contain enough lysine and methionine, and some of them also do not supply enough arginine and cystine, the oil-seed meals supply more than enough to make up the deficiency.

Minerals.—*Calcium and phosphorus.*—The calcium requirement of laying chickens is very high because of the relatively large quantity of this element used in making eggshells. However, a large excess of calcium in the diet adversely affects the hatchability of the eggs. Comparatively little is known about the phosphorus requirement of laying chickens, but there is evidence that a high level of phosphorus intake increases the calcium requirement. For this reason it is desirable to control both the calcium and phosphorus intake.

A chicken that lays 200 two-ounce eggs per year puts into those eggs about 400 grams of calcium, or about 13 to 15 times as much as there is in her entire body. If the diet is deficient in calcium, a chicken can draw on its skeleton for only enough calcium to make 3 or 4 eggs. From these statements it is evident that the feed must supply virtually all the calcium that goes into the eggs.

Both experimental results and theoretical considerations indicate that the proper perecentage of calcium in the diet depends on (1) the number of eggs laid per bird, (2) the quantity of feed consumed, and (3) the phosphorus content of the diet. When the average egg production and average feed consumption of a flock are known or can be predicted, the following formula may be used for computing the proper calcium content of the diet:

$$Ca = 1.292P + \frac{0.41E}{F}$$

In this formula,

Ca = the proper per cent of calcium in the diet,
P = the per cent of phosphorus in the diet,
E = the average number of eggs laid per bird per year, and
F = the number of pounds of feed consumed per year.

The following example illustrates the application of this formula. A poultryman has a flock of White Leghorn pullets which, according to the performance of the parent stock, should produce about 200 eggs per year. The average weight of the parent stock (females) during the pullet year was 3.75 pounds and their average feed consumption per year was 72 pounds per bird. (According to table 5, the average feed consumption of pullets that lay 200 eggs per year and have an average weight of 3.75 pounds should be about 71.5 pounds.) An analysis of the feed shows that it contains 1.1 per cent of phosphorus. On substituting the required numerical data in the formula, the proper calcium content is found to be:

$$Ca = (1.292 \times 1.1) + \frac{0.41 \times 200}{72} = 1.4212 + 1.1389 = 2.5601$$

Thus, it is found that the feed should contain about 2.56 per cent of calcium.

Inasmuch as the laying chicken can very readily adapt her physiological processes to diets containing appreciably more calcium and phosphorus than she needs, it is possible to set up standards for the calcium and phosphorus content of the diet that will be applicable under all ordinary conditions. Accordingly, there is shown in table 6 approximately how much calcium diets of different phosphorus content should contain.

If laying chickens are fed diets containing the percentages of calcium and phosphorus shown in this table, additional calcium in the form of oystershell, limestone grit, or calcite grit need not—and should not—be supplied.

Table 7. The corresponding percentages of phosphorus and calcium for all-mash diets and for mashes with which grain is to be fed.

All-mash diets		Laying mashes (with which grain is to be fed)	
Phosphorus content	Calcium content	Phosphorus content	Calcium content
Per cent	Per cent	Per cent	Per cent
0.6	1.9	0.8	3.7
0.7	2.0	0.9	3.8
0.8	2.1	1.0	3.9
0.9	2.3	1.1	4.1
1.0	2.4	1.2	4.2
1.1	2.5	1.3	4.3
1.2	2.7	1.4	4.4
1.3	2.8	1.5	4.6

Many poultrymen prefer not to have all the calcium in the feed but to have a part of it in the feed and give their chickens access to calcareous grit, such as oystershell, limestone, or calcite. Moreover, many feed manufacturers hesitate to put the full quantity of calcium in their feeds. For these two reasons very few formula feeds for laying chickens contain enough calcium, and the additional quantity that is required must be fed in the form of a calcareous grit.

In those instances in which it is not the practice or desire of the feed manufacturer to put all the required calcium in the feed, it is suggested that in the case of all-mash feeds he include about 75 per cent of the quantity indicated by table 7, and that in the case of mashes, with which grain is to be fed, he include about 50 per cent of the quantity indicated by table 7.

Occasionally, the feed of laying chickens may not contain enough phosphorus, especially if it contains very little or no dried skim milk, dried buttermilk, fish meal, meat scrap, or bone meal. In case the total phosphorus content of the diet is appreciably less than 0.7 per cent, enough steamed bone meal, defluorinated phosphate, or other low-fluorine source of phosphorus should be added to bring it up to at least this value.

Sodium and chlorine.—So far as is known, the salt requirement, expressed as per cent of the total feed, is the same for laying chickens that it is for growing chicks. Hence, a satisfactory allowance of added salt in the total feed of laying chickens is 0.30 per cent (0.25 to 0.40%, depending on the sodium chloride content of the other ingredients of the feed).

Manganese.—Since 1936 it has become a rather general practice to add 4 ounces of feeding grade manganese sulphate (65% $MnSO_4$) to each ton of all-mash laying and breeding feed, and 8 ounces to each ton of mash with which grain is to be fed. This is considerably more than is necessary but is not harmful in any way. A number of workers have studied the manganese requirement of the laying chicken, and the consensus is that it is only about 15 milligrams per pound of feed, or approximately 35 PPM. Thus, the manganese requirement of the laying chicken is only about 70 per cent as large as that of the growing chicken.

Inasmuch as typical feed mixtures for laying chickens rarely contain less than 30 PPM of manganese, it is not necessary to add more than 5 to 10 PPM of manganese to all-mash feeds, or more than 35 to 40 PPM to mashes with which grain is to be fed. The 5 to 10 PPM of manganese is supplied by ⅔ to 1⅓ ounces of feeding grade manganese sulphate per ton of feed, and the 35 to 40 PPM is supplied by 4⅔ to 5⅓ ounces. Notwithstanding, it is simpler for the feed manufac-

turer to include the same quantities of manganese sulphate in feeds for laying chickens that he includes in feeds for growing chickens. Thus, a satisfactory inclusion of manganese sulphate in all-mash laying feeds is 2⅔ ounces per ton, and in mashes with which grain is to be fed it is 5⅓ ounces per ton.

Iodine.—The iodine requirement of the laying chicken is not known, but it may be assumed that it is the same as that of the growing chicken. On the basis of this assumption, a satisfactory allowance of iodine, in the feeding of laying and breeding stock, is 2 to 5 PPM. If the feed is to contain this quantity, it usually is necessary to add at least 2 PPM.

Other elements.—Virtually nothing is known about the laying chickens requirement for iron, copper, cobalt, potassium, magnesium, etc. Accordingly, until these requirements have been determined, it seems best to assume that they are essentially the same for the laying chicken that they are for the growing chicken.

Vitamins.—*Vitamin A.*—A satisfactory allowance of vitamin A activity for the laying chicken is about 3,300 I.U. per pound of feed. The actual requirement for the production of eggs is not in excess of 2,000 I.U. per pound of feed, but an allowance of 3,300 I.U. is desirable because vitamin A and its precursors are comparatively instable in mixed feeds. Moreover, the common sources of vitamin A activity, with the exception of most commercial vitamin A supplements, such as the feeding oils, are variable in their vitamin A potency.

It has been claimed that the laying chicken's requirement of vitamin A activity is no higher for good hatchability than it is for the production of eggs. Exceptionally good evidence has been presented in support of this claim. However, there appears to be equally

good evidence that it is desirable to have more vitamin A in the feed when hatchability of the eggs and viability of the chicks are of primary importance than when egg production is the first consideration.

The evidence in support of a greater allowance of vitamin A for hatchability than for egg production is: Apparently, only about one-third of the total vitamin A activity consumed by a laying chicken appears in her eggs. It has been found that for complete development of the embryo and for hatching about 350 I.U. are required. Accordingly, the egg should contain a minimum of 350 I.U. On the basis that the quantity of feed required by a 4-pound White Leghorn pullet for the production of an egg per day is about 110 grams per day, this quantity of feed should contain about 3 x 350 I.U. or 1,050 I. U. Hence, each pound of feed for breeding stock (light breeds) should contain about 4,500 I.U. of vitamin A activity. On the basis that the quantity of feed required by a Rhode Island Red pullet for the production of an egg per day is about 129 grams per day, the feed of breeding stock (heavy breeds) should contain about 3,700 I.U. of vitamin A activity per pound. Accordingly, a satisfactory allowance of vitamin A activity for breeding stock in general would be about 4,500 I. U. per pound of feed.

In certain feeding experiments, in which a series of diets containing graduated levels of vitamin A activity were fed, the viability of the chickens, their production of eggs, the hatchability of their eggs, and the viability of their offspring was just as good when the diet contained only about 3,300 I.U. per pound as when it contained more. The evidence supplied by these experiments indicates that ordinarily 3,300 I.U. of vitamin A activity per pound of feed is enough. Notwithstanding, in feeding breeding stock, a higher level of vitamin A activity—as much as 4,500 I.U. per pound

or even more—is to be recommended, unless the cost of the extra vitamin A activity is excessive. In many instances it will be found that the additional cost of the extra vitamin A activity is only a few cents per ton of feed.

Vitamin D.—A satisfactory allowance of vitamin D for both laying and breeding stock is 450 to 500 A.O.A.C. chick units per pound of feed. The actual requirement, however, probably is only about 250 A.O.A.C. chicks units per pound of feed. In any case, if the feed contains enough vitamin D to support a heavy production of eggs, it contains enough for maintaining good hatchability. A gross excess of vitamin D should be avoided because such an excess tends to reduce the hatchability of the eggs.

Riboflavin.—There is very good evidence that the chicken's requirement of riboflavin is larger for the maintenance of high hatchability than it is for the production of eggs. For the production of eggs, a satisfactory allowance of riboflavin is about 1.2 milligrams per pound of feed, but for the maintenance of high hatchability an allowance of as much as 1.6 milligrams per pound of feed may well be made. The chicken's actual requirement of riboflavin for egg production is, depending on the breed, between 0.8 and 1.0 milligram per pound of feed, and for the maintenance of high hatchability it is between 1.2 and 1.4 milligrams per pound of feed.

Pantothenic acid.—There is very little quantitative information about the need of the laying chicken for pantothenic acid. However, there is very good evidence that more pantothenic acid is needed for maintaining high hatchability than is needed for maintaining a high rate or egg production. A satisfactory allowance of pantothenic acid for egg production is about 4.5 milligrams per pound of feed, and for main-

taining high hatchability, about 5.5 milligrams per pound of feed. Apparently, the actual requirement for egg production is only about 3.5 milligrams per pound of feed, and for maintaining high hatchability, only about 5 milligrams per pound of feed.

Choline.—A desirable allowance of choline for laying chickens is about 500 milligrams per pound of feed, but an allowance of 450 milligram—or even a little less appears to be satisfactory.

Pyridoxine.—Apparently, if the feed of the laying chicken contains enough pyridoxine to support egg production at a good rate, it contains enough to maintain high hatchability. A satisfactory allowance of pyridoxine is about 1.5 milligrams per pound of feed, but the actual requirement appears to be only about 1.0 milligram.

Biotin.—The laying chicken's requirement of biotin for maintaining high hatchability has been reported to be 70 micrograms (0.07 milligram) per pound of feed.

Other vitamins.—The quantitative requirements of the laying chicken for the other vitamins are not known. For good hatchability, however, it is probable that the laying chicken's requirements of the other essential vitamins are at least as large as those of the growing chicken.

Nutrient Allowances for Market Chickens

The nutrient requirements of chickens that are being finished, or fattened, for market depends on their age. Broilers should be fed essentially the same kind of diets that are usually fed to growing chickens, but fryers, roasters, capons, and fowls are best finished on diets that contain appreciably less protein and somewhat more fat.

Ordinarily, no special advantage is gained by feeding broilers a special finishing diet; however, if the growing diet contains fish oil or fish meal, it is a good practice to omit them for at least two weeks before the broilers are killed and dressed, otherwise the flesh of the chickens may have a slight fishy taste. Nevertheless, experience has shown that some fish meals—notably domestic sardine meals—ordinarily do not affect the flavor of the flesh of the chickens, and need not be omitted from the diet at any time.

Sometimes a special finishing diet is fed to broilers during a period of several days before they are killed. This is done for the purpose of improving the quality and, hence, the value of the carcass. The nature of the finishing diet is determined by the stage of growth of the chickens. Finishing diets for broilers should contain about 18 per cent of protein (air-dry basis), and they should contain the same quantities of the vitamins and minerals as a growing diet. It is desirable to include in the feed vitamin D at the rate of about 180 A.O.A.C. chick units per pound to prevent the development of brittle wing and leg bones. The source of vitamin D should be D-activated animal sterol rather than fish oil, because the latter might impart an undesirable flavor to the flesh.

Finishing diets for fryers, roasters, capons, and fowls (mature female birds of any age or weight) need not contain more than 12 to 14 per cent of protein. The quantities of the several vitamins, except vitamin A, may be reduced to about one-half of those ordinarily used in feeding growing chicks. It is desirable that the feed (air-dry basis) contain at least 1,800 I.U. of vitamin A and at least 90 A.O.A.C. chick units of vitamin D (from D-activated animal sterol) per pound. Also, it is desirable that the feed for these classes of chickens contain about 1.0 per cent of calcium and about 0.5 per

cent of phosphorus. By using these quantities of vitamin D, calcium, and phosphorus the number of brittle wing and leg bones will be reduced to a minimum.

Finishing diets that are fed especially for the purpose of improving the quality of the carcass should contain between 6 and 10 per cent of fat (air-dry basis). Most of the usual mixtures of feedstuffs used in finishing poultry for market do not contain this much fat, unless some is added. Corn oil is an unusually good source of additional fat. Other oils, such as red palm oil, rapeseed oil, and peanut oil may be used. Mutton tallow has been used, and is still used at times, but it is not so readily mixed with the feed as are the oils just mentioned. The quantity of oil, or mutton tallow, to add to a finishing diet depends on the fat content of the diet; ordinarily the proper quantity to add is between 2.5 and 6 per cent.

Nutrient Allowances for Segregated Breeding Males

When young males to be used for breeding are segregated from the females, they should be fed in the same manner as other growing chickens until they are about 9 months old. After this age is reached, their nutritive requirements are met by a diet that contains 13 to 14 per cent of protein, 0.4 to 0.6 per cent of phosphorus, and 0.6 to 0.9 per cent of calcium. The allowances of certain of the vitamins should be, per pound of feed, approximately as follows: Vitamin A, 2,000 I.U.; vitamin D, 75 A.O.A.C. chick units; and riboflavin, about 1.0 milligram.

QUALITY OF FLESH AND EGGS AS AFFECTED BY DIET

There is an ever increasing demand for the best grades of table poultry and eggs. Inasmuch as the best grades almost invariably command appreciably higher prices than the less desirable grades, it is to the advantage of every poultryman to produce products of the very highest quality. If eggs and meat of this quality are to be produced, and if the greatest profit possible is to be realized, the chickens must be properly fed, and feedstuffs that have an undesirable effect on the resulting products must be avoided or, at least, used with caution.

Flavor of Chicken Flesh and Eggs

Although the feed consumed has only a slight effect on the proximate chemical composition of eggs, certain feedstuffs, such as onions, rape, turnips, and some fish meals, have been reported to have an undesirable effect on the flavor, if they are fed in sufficient quantity. On the other hand, both the proximate chemical composition of chicken flesh and its flavor may be affected by the feed.

Often, however, the feed is blamed as the cause of off flavors in eggs, when the real cause is contamination of the eggs after they are laid. For example, many disinfectants, if accidentally sprayed on the nests, will impart undesirable flavors to the eggs laid in those nests. Moreover, if buckets, in which there recently have been onions or garlic, are used in collecting eggs from the nests, many of the eggs will acquire an undesirable flavor. In at least a few instances, in which fish oil and fish meal in the feed had been blamed as

the cause of fishy flavor in eggs, it was easy to demonstrate that the real cause of the fishy flavor was the use of dirty buckets for collecting the eggs. The buckets recently had had some fish oil in them and had not been properly cleaned.

Fishy flavor in chicken flesh.—Sometimes the flesh of chickens is found to have an undesirable flavor described as "fishy." Such a flavor may be observed even though the feed contained no fish oil or fish meal; however, when such a flavor is encountered, it usually will be found that fish oil or fish meal or both have been fed up to the time the chickens were killed.

There is some evidence that certain compounds that have a highly undesirable fishy odor and flavor may be produced by the interaction or combining of certain free fat acids and trimethylene oxide, which is commonly present in fish meal. Apparently, also, there are in some plants certain nitrogen-containing compounds, known as betaines, that may also combine with any free fat acids and yield products that have a fishy odor and flavor.

In order to prevent the occurence of fishy flavor in chicken flesh, it is recommended that rancid feedstuffs never be fed, and that all fish oil and fish meal be removed from the diet at least two weeks before the chickens are killed. Furthermore, special care should be taken never to kill chickens while there still is some feed in their crops. If feed is retained in the crop, rancidity is likely to develop, and the resulting free fat acids may combine with any trimethylamine oxide or betaine present and, thus, produce undesirable flavors.

Experience has shown that not all fish meals produce a fishy flavor. Certain ones, such as domestic sardine meal, ordinarily may be fed up to the time the chicken are killed, and not have any undesirable effects, provided care is taken not to kill the chickens while

there still is feed in their crops. A very good procedure to follow is to fast the birds for about 12 to 16 hours before they are killed.

Off flavors in eggs.—When undesirable flavors are found in eggs, it is well to examine a few eggs from each chicken in the flock because an occasional bird produces eggs that have an objectionable odor or flavor regardless of the kind of feed consumed. If chickens that produce off-flavored eggs are found, they should be removed from the flock.

Desirable flavors.—It has not been found possible to improve the flavor of normal eggs by including special feedstuffs in the diet, but there is some evidence that the flavor of the flesh of chickens being finished for market can be improved in that way. For example, it has been reported that adding 2 to 4 per cent of corn oil to the finishing diet (air-dry basis) produces a very satisfactory flavor, and that adding a similar quantity of peanut oil produces a flavor described as "sweet."

Color of the Flesh and Skin and of the Yolk

Although the color of the flesh and skin of chickens is primarily a breed characteristic, it may be affected to a certain extent by the diet. If large quantities of yellow corn are fed, the color of the fat tends to be yellow. Including corn gluten meal and alfalfa meal in the diet also tends to increase the yellowness of the fat. The writer has obtained some evidence that corn oil is of value for increasing the quantity of pigment in the shanks and skin of the yellow-skin breeds. To obtain the maximum effect, it is necessary to include the corn oil in the diet only during the last 2 to 3 weeks before the chickens are marketed. About 2 per cent was found to be effective in some cases, but in finish feeding more

may be desirable from the standpoint of obtaining a large deposition of fat.

In raising broilers it is well to keep in mind that an excess of vitamin A, as such, tends to inhibit the pigmentation of the skin and shanks, whereas carotene does not. Accordingly, in formulating feeds for the production of broilers, it is desirable to obtain all or, at least, most of the vitamin A activity from carotene. This is easily done by using dehydrated alfalfa meal, corn gluten meal, and yellow corn as the principal sources of vitamin A activity and by using D-activated animal sterol as the source of vitamin D. Additional color may be put into the skin and shanks by including about 0.5 per cent of ground pimento pepper or chili pepper in the feed.

When it is desired to produce white-fleshed poultry, yellow corn, corn gluten meal, alfalfa meal, and all greed feeds should be omitted from the diet, and oats and white corn should be used in place of the yellow corn, and soybean meal in place of the corn gluten meal.

In general, the color of egg yolks may be easily controlled by feeding suitable feedstuffs. Very light colored yolks may be obtained by eliminating yellow corn, corn gluten meal, alfalfa meal, and all green feed from the diet. When this is not practicable, the pigmentation of the yolks may be reduced by feeding an excess of vitamin A, as such.

Yolks having the richer shades of yellow may be obtained through the use of yellow corn, corn gluten meal, alfalfa meal, and fresh green feed in the diet. Deep orange-red yolks may be obtained by feeding 0.5 to 2.0 per cent of ground pimento pepper or chili pepper. Cull peppers should be used because of their relative cheapness. The use of these cull peppers is not restricted, however, to the production of deeply colored

yolks. In the winter, when green feed is scarce, or not to be had at all, small quantities may be used for building up the color of the yolks.

Incidentally, the color of the white, or albumen, also may be affected by diet. A plentiful supply of green feed tends to give the white a greenish yellow, or whey, color. Rich sources of riboflavin also tend to produce this greenish-yellow color.

Cottonseed meal has an undesirable effect on the color of both the yolk and the white. If large quantities (35 to 40 per cent) of cottonseed meal are fed, the yolks of the eggs may have a brown mottled appearance when laid. And, even if comparatively small quantities are fed, the yolks of the eggs tend to acquire a similar appearance after the eggs have been in cold storage for 6 weeks or longer. Cottonseed meal and some weeds of the same botanical family as the cotton plant tend to produce a pink tint in the white. These undesirable effects of cottonseed meal may be prevented by including a small quantity of an iron salt—either ferrous or ferric—in the feed. As little as 0.5 per cent of ferric chloride appears to be effective.

Blue, green, and red yolks.—Novelty eggs having yolks of a pronounced color, such as blue, green, and red, may be produced by feedind certain alcohol-soluble dyes to laying hens. These dyes are best fed at the rate of 20 milligrams per day in gelatin capsules. Hexyl blue colors the yolks blue, it also gives a deep blue color to the external as well as abdominal fat. Oil Red A imparts a blood red color to the yolk. Green colored yolks may be obtained by feeding either Alizarol Purple SS or Alizarine Cyanine Green F. Oil Brown D, a brown dye, gives a magenta color to the yolks. Comassie Fast Black imparts a pink color, and Spirit soluble Nigrasine a light green tint. None of these dyes has been approved by the Food and Drug

Administration for use in foods. Accordingly, eggs from hens that have received these dyes should not be sold for use as human food.

White yolks.—Eggs having white — or almost white—yolks may be obtained by feeding a diet, all the ingredients of which have a very low content of carotenoid pigments. Suitable ingredients for such a diet include, white corn, pulverized oats, feeding oat meal, certain fish meals (e.g., menhaden fish meal), dried skim milk, dried whey, salt (or salt mixture), ground limestone, and feeding oil of suitable potency.

NUTRITIONAL DISEASES, AND VICES

Slow growth, poor production, many diseases, and heavy mortality are often the indirect result, and sometimes the direct result, of nutritional deficiencies; occasionally, they are the result of nutritional excesses. In general, properly fed chickens grow well, lay well, and are healthy. It is important, therefore, that the poultryman be able to recognize the symptoms of nutritional deficiencies.

Many nutritional deficiencies produce the same general symptoms. Satisfactory growth cannot be obtained on a diet deficient in minerals, amino acids, or vitamins, or when the total intake of energy is insufficient. An inadequate quantity of any one of the essential mineral elements, amino acids, or vitamins retards growth. For example, good growth does not result if the diet is markedly deficient in sodium, even though all the other necessary mineral elements, as well as the amino acids and vitamins, are present. Moreover, poor feathering and the appearance of general weakness may result from a deficiency of any one or more of the essential nutrients.

For the reasons mentioned above, it not always is possible to recognize the cause from the symptoms. However, some deficiencies produce more or less characteristic symptoms, and these will be discussed.

Deficiency of Vitamin A

If day-old chicks are fed a diet that is markedly deficient in vitamin A, their rate of growth falls below normal after about 2 weeks and then declines very rapidly. The first characteristic symptoms, other than the decrease in rate of growth, are droopiness, a

staggering gait, and a ruffled appearance of the feathers. These symptoms may appear as early as the end of the third week. Some of the chicks die before the end of the fourth week, and most of the others die before they are 5 weeks old. Growth usually ceases several days before death occurs.

In many of the chicks that survive for more than a week after the first characteristic symptoms appear, the eyes become inflamed and there is a discharge from the nostrils; in some chicks there are swelling around the eyes and an accumulation of sticky exudate beneath the lids.

If the diet is only partially deficient in vitamin A, the first symptoms may not appear until the chicks are 5 or 6 weeks old. In that case, a larger proportion of the chicks eventually have inflamed eyes and an accumulation of white cheesy material under the lids. Nearly all the chicks exhibit a marked nervousness.

In mature chickens symptoms of vitamin A deficiency develop much more slowly than in growing chicks, but the inflammation of the eyes becomes strikingly more pronounced. Often there are a white membranous film over the nictitating membrane, or third eyelid, and a cheesy exudate or discharge, in the conjunctival sacs. There also may be a sticky discharge, either clear or turbid, from the nostrils.

Findings after death.—An examination of chickens that die as a result of a deficiency of vitamin A reveals lesions, or changes in the tissues, in many parts of the body. The location and severity of these lesions depend to some extent on the age of the chicken, the degree of the deficiency, and the length of time between the appearance of the first symptoms and death.

In mature chickens lesions resembling pustules almost invariably are found in the mouth, pharynx, and esophagus; in young growing chickens these lesions are

seen much less frequently. Usually there are white or grayish-white deposits of urates in the kidneys and ureters. Sometimes there are deposits of urates on the surface of the heart, liver, and spleen. Uratelike deposits are frequently found between thickened folds of the bursa Fabricii.

In general, there is a keratinization, or hornlike hardening, of the epithelial cells of the olofactory, respiratory, upper ailmentary, and urinary tracts. In severe cases, especially if the chickens are mature, virtually every organ in the body may be affected. Also, there are degenerative changes in both the central and peripheral nervous systems; and these explain the staggering gait, which is one of the first symptoms of a deficiency of vitamin A in chickens, and the extreme lack of muscular co-ordination in advanced cases.

Function of Vitamin A.—Histological examinations of the tissues of chickens that have been fed a diet deficient in vitamin A indicate that one of the functions—if not the primary function—of vitamin A is the proper nourishment and repair of all epithelial structures, external and internal, of the body. In extreme deficiency of vitamin A in the chicken the uric acid content of the blood may increase to eight or nine times its normal value. The accumulation of uric acid in the blood and the previously-mentioned occurrence of deposits of urates in the ureters, the kidneys, and elsewhere are probably results of failure of repair of epithelial structures, especially those of the kidneys.

Vitamin A has been referred to as the anti-infective vitamin, but repeated attempts to show that it affects the mechanisms that give the body immunity against infections have failed. When the diet is deficient in vitamin A, however, the epithelium of the mucous membranes is damaged, and as a result the entry of bacteria is made easier. Thus, although vitamin A is of

no value in making an animal immune to infectious diseases, it is of value in maintaining the "first line of defense," the epithelial structures.

Deficiency of Vitamin D, Rickets, and Osteoporosis

Abnormal development of the bones of growing chickens and other kinds of poultry may result from a number of dietary causes, among which are (1) a deficiency of one or more of the following nutrients: Vitamin D, calcium, phosphorus, manganese, choline, biotin, folic acid, and possibly others; (2) a marked imbalance of calcium and phosphorus, and of other nutrients as well; and (3) the presence of certain substances that make the vitamin D or phosphorus unavailable. The discussion here is restricted to those conditions in which the absorption and metabolism of vitamin D, calcium, and phosphorus are directly involved. The condition known as perosis is discussed later.

Some students of animal nutrition distinguish between rickets and another condition of the bones, osteoporosis, on the ground that the former is the result of a deficiency of phosphorus and the latter, of a deficiency of calcium. The distinction is warranted because the changes that occur in the bones are not the same in the two conditions. However, both may be prevented or cured by including sufficient vitamin D in the diet, unless there is a marked deficiency of phosphorus or of calcium.

At the time of hatching, the chick is essentially osteoporotic, that is, its bones have a much lower calcium-phosphorus ratio than they do later on; hence, it requires an immediate supply of calcium in its diet. If the diet is markedly deficient in calcium, or if that which is present is unavailable as a result of a defi-

ciency of vitamin D, the osteoporotic condition becomes more pronounced. If, however, the diet contains an adequate quantity of calcium but an inadequate quantity of phosphorus or of vitamin D or both, rickets develops.

Rickets may be produced on diets that contain adequate quantities of vitamin D, calcium, and phosphorus if the diets also contain large quantities of certain inorganic compounds, such as soluble salts of iron, lead, and beryllium. This is because iron, lead, and beryllium form insoluble compounds with the phosphorus and make it unavailable. Excessive quantities of calcium in the diet of growing chicks may also make much of the phosphorus unavailable as a result of the formation of calcium phosphate, which is relatively insoluble in the presence of an excess of the calcium ion. A diet deficient in vitamin D is, therefore, more rachitogenic if it contains an excessively large quantity of calcium than if it contains a much smaller but adequate quantity.

A condition called sulphur rickets may result from the inclusion in the diet of 2 per cent or more of sulphur for the control of coccidiosis. If the particles of sulphur are very small (e.g., colloidal), less than 2 per cent may cause this condition. Inasmuch as sunshine appears to be completely effective in preventing sulphur rickets, it seems likely that sulphur causes rickets by preventing the absorption of vitamin D from the intestinal tract. Sulphur rickets is relieved but not entirely eliminated by doubling or trebling the vitamin D in the diet.

The rickety and osteoporotic conditions encountered in the practical production of poultry are more frequently caused by a deficiency of vitamin D than by a deficiency of calcium or phosphorus, or by the presense in the diet of large quantities of soluble salts of iron, lead, or beryllium.

Symptoms of a deficiency of vitamin D.—If a diet deficient in vitamin D is fed, beginning with the first feeding, the first outward symptoms in the chick usually make their appearance toward the end of the fourth week. If the deficiency is not relieved, most of the chicks die within about 8 weeks.

The first symptoms of a deficiency of vitamin D in the growing chicken are a tendency to rest frequently in a squatting position, a disinclination to walk, and a lame, stiff-legged gait. These symptoms differ from those of a deficiency of vitamin A in that in vitamin D deficiency the chick at first is alert rather than droopy and walks with a lame rather than a staggering gait. Other symptoms, in the usual order of their occurrence, are retardation of growth, enlargement of the hock joints, beading at the ends of the ribs, and a marked softening of the beak. As in many other diseases of poultry, the feathers soon acquire a ruffled appearance.

It has been reported that the wing feathers of 4-week-old New Hampshires contain an abnormal black pigment, if a diet deficient in vitamin D has been fed. The blackening is very marked, and may extend to nearly all the feathers if the deficiency is severe. If vitamin D is supplied in sufficient quantity, the new feathers and the newer part of the older feathers have the normal red color. The blackened portion of the feathers remains black and is not affected by feeding vitamin D.

In the adult female chicken the first symptom of a deficiency of vitamin D is a thinning of the shells of its eggs. If the deficiency is marked, there is a fairly prompt decrease in both egg production and hatchability. After a time the breast bones become distinctly less rigid. If the deficiency is severe and prolonged, the chickens may lose the use of their legs. Adult chickens,

however, are able to live for months on a diet that supplies practically no vitamin D.

Gross changes and chemical findings.—In the chick, a deficiency of vitamin D produces marked changes in the bones and the parathyroid and thyroid glands and variable changes in the calcium and phosphorus content of the blood. The bones may be soft or only moderately so, but in any case their content of ash is much less than that of normal bones. In some instances the ash content of the tibias may be at little as 27 per cent on a moisture-and-fat-free basis. (The normal ash of the tibias of young chicks is about 46 per cent.) The epiphyses, or growing ends, of the long bones are greatly enlarged. The parathyroid becomes enlarged, sometimes to eight times its normal size, as a result of an increase in both the size of the cells and the number of epithelial cells. At most there is no great change in the weight of the thyroid, but there is an appreciable increase in the number of cells.

The changes in the calcium and phosphorus content of the blood depend on the calcium and phosphorus content of the diet. If the diet has a low calcium content, the calcium content of the blood may be approximately normal and the phosphorus content high. In such a case the bones tend to be somewhat rarefied rather than soft. If there is a deficiency of both calcium and phosphorus in the diet, the blood may contain less than normal quantities of these elements. When there is a deficiency of phosphorus, the bones tend to be soft and may be bent.

In adult chickens a deficency of vitamin D eventually produces changes in the parathyroid similar to those produced in chicks. The bones tend to become rarefied (osteoporotic) rather than soft.

Function of vitamin D.—It must be concluded that vitamin D is required for the normal metabolism

of calcium and phosphorus in the chicken, but the exact manner in which it performs its function is not known. A diet deficient in vitamin D does not produce rickets in the rat if it contains suitable quantities of calcium and phosphorus; but rickets is always produced in the chicken by a deficiency of vitamin D, even when the diet contains calcium and phosphorus in adequate quantities. There is good evidence that in the rat vitamin D regulates the absorption of calcium and phosphorus from the intestine, and it is highly probable that it performs the same function in the chicken. It also is highly probable that vitamin D acts as a physiological moderator of the parathyroid gland.

Deficiency of Vitamin E

Nutritional encaphalomalacia, or "crazy chick disease," is easily produced experimentally in young chicks by feeding a diet high in fat but markedly deficient in vitamin E. The development of encephalomalacia on such a diet may be prevented by the oral administration of small quantities of alpha-tocopherol (vitamin E) to the chicks. The syndrome, or group of typical symptoms, of encephalomalacia may be produced in young chicks by adding an excessively large quantity of cod-liver oil to their diet. The quantity of cod-liver oil required for the consistent production of the syndrome is about 5 per cent of the total feed; however, 3 per cent usually will cause all the typical symptoms to appear in at least a few of the chicks.

Deficiency of vitamin E is comparatively rare in practice. It may occur, however, when a rancid feed is fed or when a poultryman adds to feed he has purchased an excessively large quantity of feeding oil.

Symptoms of nutritional encephalomalacia.—When a diet high in fat but markedly deficient in vitamin E is fed to day-old chicks, symptoms of encephalo-

malacia may occur as early as the seventh and as late as the fifty-sixth day, but the highest incidence is between the fifteenth and thirtieth days after hatching. In older chicks the average number of days before the onset of the disease depends on the age at which the deficient diet is first fed; the older the chicks are, up to 8 weeks of age, the more quickly they are affected. The disease rarely occurs among chicks more than 8 weeks old.

The symptoms of nutritional encephalomalacia are described very well by the popular name of the disease, "crazy chick disease." When the chicks attempt to walk, they often fall forward, backward, or to one side and then wheel in circles. In advanced cases there frequently is complete prostration, with the legs extended, the head sometimes retracted, and tremors of both head and legs.

Extensive lesions are usually found in the brains of chicks that have died of nutritional encephalomalacia. The cerebellum (the hind part of the brain) is most commonly affected; but in somewhat more than 25 per cent of all cases lesions are found also in the cerebral hemispheres, and in about 12 per cent of all cases in the medulla. In some cases, four-fifths of the cerebellum may be affected, and in the others the lesions may be so small that they cannot be detected with the unaided eye.

Other symptoms of deficiency of vitamin E.—In general, the syndrome of vitamin E deficiency depends upon the type of diet that is fed. One typical set of symptoms has been referred to as alimentary exudative diathesis, which is characterized by accumulations of large quantities of transparent fluid in the subcutaneous tissues. The accumulations are found in various parts of the body but most frequently in the breast and abdomen. The fluid has essentially the same composi-

tion as blood plasma and clots readily. In addition to the accumulations of fluid, hyperemia, slight hemorrhage, and accumulation of white blood corpuscles in connective tissues may be observed. A generalized edema may also be produced by feeding certain types of diets that are deficient in vitamin E. The onset of the symptoms may be hastened by causing the chicks to drink water of high salt content. As a matter of fact, edema may be produced in this way even when the diet is not deficient in vitamin E.

Deficiency of Vitamin K

If very young chicks are fed a diet deficient in vitamin K, the time required for their blood to clot begins to increase after 5 to 10 days and becomes greatly increased after 7 to 12 days. After about a week on such a diet, hemorrhages often occur in any part of the body, spontaneously or as the result of an injury or bruise. The only external symptoms of a deficiency of vitamin K are the resulting accumulations of blood under the skin.

Chicks on a diet deficient in vitamin K become anemic after a time as a result of the hemorrhages. Examination after death often reveals accumulations of blood in various parts of the body, and invariably there are erosions of the gizzard lining.

The symptoms of a deficiency of vitamin K may be produced quite easily in the laboratory, but they are seldom if ever observed when the chicks are raised in the usual manner. The age at which the diet deficient in vitamin K is first fed influences the development of the resulting condition. The younger the chicks are, the more susceptible they are. The disease normally does not occur in chicks more than a few weeks old. Hemorrhages may be produced within 12 to 20 days in adult chickens, however, by tying off the bile ducts. This in-

dicates that bile is necessary for the absorption of vitamin K.

Just how vitamin K functions is not known; apparently, however, it is necessary for the formation of prothrombin, which in turn is necessary for the normal clotting of blood.

Deficiency of Thiamine

A diet containing little or no thiamine (vitamin B_1) but otherwise adequate causes a prompt decrease in appetite, followed soon by a steady decline in weight. After 7 to 10 days there is a progressive development of general paralysis. The extensor muscles of the legs are the first to become affected, but soon the paralysis extends to the wings and neck and, finally, to all the muscles. In the early stages of paralysis the chicken swallows feed or water with great difficulty; in the later stages the body temperature falls, and the head is raised and drawn back. Death follows, usually within 1 or 2 days after the typical symptom of head retraction appears.

When the diet is only partially deficient in thiamine, 30 days or more may elapse before the symptoms of paralysis appear. There are marked individual differences in the ability of chickens to survive on diets that are partially deficient in thiamine. In adult and nearly grown chickens there is a loss of about 20 per cent of the initial weight before death occurs.

Deficiency of Riboflavin

The characteristic symptom of a deficiency of riboflavin (vitamin G) in the chick is a condition referred to as curled-toe paralysis, but this condition does not occur if the diet is markedly deficient, because the chick dies before the paralysis develops. If a small but inadequate quantity of riboflavin is added to a diet that

is markedly deficient in this vitamin, the paralysis occurs; and if an adequate quantity is added, the paralysis is prevented. Other symptoms of a deficiency of riboflavin are a marked decrease in the rate of growth or even complete failure to grow, diarrhea after 8 to 10 days, and a high rate of mortality after about 3 weeks. There is no impairment of the growth of the feathers; on the contrary the main wing feathers often appear to be disproportionately long.

Histological findings in deficiency of riboflavin.—A deficiency of riboflavin produces specific changes in the main peripheral nerve trunks. In acute cases there are hypertrophy of the nerve trunks and a readily observable change in their appearance. Degenerative changes also appear in the myelin of the nerves. There may also be congestion and premature atrophy of the lobes of the thymus. Apparetly, the kidney, thyroid, and suprarenal glands, brain, and brain stem are not affected.

Deficiency of Pantothenic Acid

When a diet deficient in pantothenic acid is fed to young chicks, their growth becomes retarded and their feathers acquire a ragged appearance. Within 12 to 14 days the margins of the eyelids of the chicks become granulated, and frequently a viscous exudate, which causes the eyelids to stick together, is formed. Crusty scabs appear at the corners of the mouth, and the skin on the bottoms of the feet often becomes thickened and cornified. At first there is no loss of down or feathers, but after about 18 weeks complete loss of feathers in limited areas on the head and neck may occur.

The characteristic dermatitis produced in chicks by feeding diets deficient in pantothenic acid has not been found in adult chickens fed similar diets. However, it

has been demonstrated a number of times that a deficiency of pantothenic acid causes a reduction in hatchability.

Findings after death.—It has been reported that on post mortem examination of the affected chicks a puslike substance is frequently observed in the mouth, and an opaque, grayish-white exudate in the proventriculus. Usually, the entire intestinal tract contains little or no feed residues, the small intestine in atrophic, and the kidneys are inflamed or hemorrhagic. Lesions of the spinal cord, characterized by a myelin degeneration of the myelinated fibers, occur in chicks that are fed a diet deficient in pantothenic acid. Degenerating fibers may be found in all segments of the spinal cord down to the lumbar region. Involution of the thymus and liver damage have also been reported.

The manner in which pantothenic acid functions in the chicken is not known, but the existing evidence indicates that it is necessary for the maintenance of a normal spinal cord in the growing chicken.

Occurrence of pantothenic acid deficiency.—Most of the feedstuffs ordinarily included in feed mixtures for poultry are fairly good sources of pantothenic acid. However, diets composed largely of the cereal grains and containing the usual quantities of meat scrap or fish meal or both, but no milk products, may contain less of this factor than is required by the growing chick. It may be pointed out that the kiln-drying of corn tends to destroy much of the pantothenic acid originally present.

Although milk by-products are among our best sources of pantothenic acid, one need not depend on them to avoid a deficiency of this vitamin. Among the feedstuffs, other than milk byproducts, that contain as much or more pantothenic acid than dried skim milk are peanut meal, liver meal, dehydrated alfalfa

meal, yeast, and some lots of cane molasses. Other good sources are dried distillers' solubles and wheat bran.

Deficiency of Pyridoxine

Deficiency of pyridoxine (vitamin B_6) rarely if ever occurs among chickens fed more or less typical diets. In the laboratory the symptoms may be produced by feeding special diets. When a diet deficient in pyridoxine is fed, there is a loss of appetite followed by a marked reduction in growth and poor development of the feathers. The efficiency of feed utilization is greatly reduced. Many of the chicks have fits and convulsions, and the convulsions usually end in complete exhaustion and, sometimes, in death.

Deficiency of pyridoxine produces anemia and hyperprothrombinemia. As a result of the increase in prothrombin, the clotting time may be reduced to about one-fifth of its normal value, but usually to only about one-half of its normal value. It has been reported that the spleens of chicks on a diet deficient in pyridoxine tend to be smaller than those of chicks on adequate diets.

Deficiency of Niacin

Apparently, acute niacin (nicotinic acid) deficiency in the chicken occurs only when the diet is deficient in tryptophane as well as niacin. The reason is that tryptophane is a precursor of niacin. Accordingly, certain practical diets for chickens may be deficient in niacin because they do not contain enough tryptophane for both normal growth (or repair of tissues) and the formation of niacin.

Usually the only symptom of a deficiency of niacin is poor growth. If, however, the deficiency is pronounced and the protein of the diet supplies insufficient tryptophane, a marked inflammation of the tongue,

oral cavity, and esophagus develops. The syndrome is the analogue of "blacktongue" in the dog. In chronic cases of niacin deficiency, feed consumption is markedly reduced, the feather development is poor, and a scaly condition of the feet may develop.

Perosis is common among chicks on diets deficient in niacin and tryptophane.

Obviously, the niacin requirement of the chicken depends on the protein in the diet. Large quantities of corn, corn gluten meal, and meat scrap in the diet increase the niacin requirement. The niacin requirement may also be increased by adding gelatin to a diet that otherwise contains enough niacin. However, if the diet contains enough tryptophane, the niacin requirement depends on the chicken's ability to synthesize niacin. Admittedly, however, the chicken is unable to synthesize enough niacin to maintain a rapid rate of growth.

Deficiency of Biotin

If a diet deficient in biotin (vitamin H) is fed to young chicks, the first symptom of disease appears in about 3 weeks. Often this is a roughening of the skin at the corners of the mouth below the lower mandible; it is most readily noticeable where the skin joins the mandible. Simultaneously fissures appear in the skin on the bottoms of the feet. Sometimes, however, the feet are affected before lesions under the mandible become apparent. Later the lesions on the lower mandible may spread around the corners of the mouth and upward until the eyes become affected and stick shut. If the chicks survive long enough, the fissures on the bottoms of the feet become numerous and very deep, hemorrhages occur, and sometimes one or more toes may slough off.

The symptoms of a deficiency of biotin and of a deficiency of pantothenic acid are similar, but the two

conditions may be distinguished from each other: In biotin deficiency the first symptom usually is the roughening of the skin below the lower mandible, whereas the characteristic dermatitis resulting from a deficiency of pantothenic acid first appears at the corners of the mouth and is seldom seen below the mandible. Moreover, in biotin deficiency the feet become involved as soon as the eyes, whereas in pantothenic acid deficency dermatitis of the feet is rarely seen and then only in the later stages—usually 2 or 3 weeks after dermatitis has appeared at the corners of the mouth. Also, the eyes are affected sooner in pantothenic acid deficiency than in biotin deficiency.

Biotin deficiency is easily produced by feeding a diet in which a rather large part of the protein is derived from egg white. When produced in this way, it was formerly called egg-white injury. Even as little as 5 per cent of dried egg white or an equivalent quantity of liquid egg white in certain diets produces the characteristic symptoms. The symptoms do not appear if 5 to 10 times as much egg yolk as egg white is also included in the diet. Also, the symptoms may be prevented from developing by including in the diet large quantities of skim milk, or about as much dried liver as egg white, or by cooking the egg white before it is included in the diet.

Egg white contains a substance called avidin which combines with biotin and inactivates it.

There is a high incidence of perosis in biotin deficiency.

Deficiency of Folic Acid

The characteristic symptoms of a deficiency of folic acid are slow growth, poor feather development, and macrocytic hypochromic anemia. The incidence of severe perosis is high among chicks on diets deficient in folic acid.

Although the growing chick's requirement of folic acid is given as 0.25 milligram per pound of feed, it has been demonstrated that it varies with the type of diet that is fed. The type of carbohydrate used in experimental diets for studying deficiency of folic acid affects quite markedly the requirement of the chick for this vitamin.

Perosis: Deficiencies of Manganese and Choline

If young chicks are fed a diet deficient in manganese, symptoms of perosis will develop within 2 to 10 weeks, depending on the severity of the deficiency, the breed and strain of chicken, the composition of the diet, and the age at which the deficient diet is first fed. If the deficient diet is fed from the first feeding, that is, when the chicks are 1 or 2 days old, the symptoms generally develop between the ages of 3 and 6 weeks, but if it is not fed until the chicks are 10 weeks old, the usual symptoms may not appear.

The first readily noticeable symptom is a tendency on the part of some of the chicks to rest for long periods in a squatting position. If the tibotarsal joints, or hocks, of these chicks are carefully examined, a slight puffiness may be observed. Within a few days the joints become slightly enlarged, and frequently the skin covering them has a bluish-green cast. Apparently, this is a critical stage, because in some cases, especially among the more resistant breeds or strains, the chicks frequently recover to such an extent that no readily noticeable permanent deformity results.

As the joints become further enlarged, they tend to become flattened, and the metatarsi, or shank bones, and tibiae exhibit a slight bending and also undergo a rotational twisting. As the condition continues to develop, the bones become more and more bent until gross

deformity results. Frequently the articular, or joint, cartilage at the lower end of the tibia slips from its normal position, and this in turn causes the main tendons to slip from their condyles. Sometimes the curvature of a tibia is so great at its lower end that the tendons slip even though the articular cartilage has not been displaced. These changes may take place in either one or both legs; when they take place in both legs, the chicken is forced to walk on its hocks.

Histological and chemical findings in perosis.—If the bones of perotic chicks are compared with those of normal chicks of about the same age and weight, it is found that they tend to be thicker and shorter. In rickets, as in perosis, the leg bones may become thickened and shortened, but the shafts are poorly calcified and tough, whereas in perosis they are well calcified and relatively brittle. In osteoporosis the shafts are of normal length and much thinner than in rickets or perosis and are somewhat more springy than in perosis. In all three conditions the upper end of the tibia becomes enlarged, but it has a bulbous shape in rickets, a conical shape in perosis, and an approximately normal shape in osteoporosis.

Other effects of a deficiency of manganese.—If adult chickens are fed a diet deficient in manganese, no observable changes in their leg joints and bones occur, but the shells of their eggs tend to become thinner and less resistant to breakage. If the deficiency is sufficiently great, egg production is decreased, and the eggs that are produced have a very low hatchability. The lowered hatchability results from an increase in the embryonic mortality that occurs after the tenth day of incubation. The embryonic mortality reaches its peak on the twentieth and twenty-first days of incubation. The embryos that die after the tenth day are chondystrophic; they have short, thickened legs, short

wings, parrot-like beaks, a globular contour of the head, protruding abdomen, and, in the most severe cases, retarded development of the down.

If the deficiency of manganese in the diet of laying hens is marked but not extreme, a few of the eggs may hatch. The resulting chicks may have very short leg bones, and in some cases the bones may be deformed as in chicks that develop perosis after hatching.

Deficiency of choline.—Perosis may occur on a diet that contains an adequate quantity of manganese, if the diet is deficient in choline. Choline deficiency also retards growth and, if the deficiency is pronounced, causes the development of fatty livers. An adequate supply of choline is claimed to be necessary for the maintenance of maximum egg production and hatchability.

Other causes of perosis.—In addition to manganese and choline, at least three other factors are necessary for the prevention of perosis. These other factors are biotin, folic acid, and niacin; it is probable, however, that comparatively little niacin is needed if the feed supplies sufficient tryptophane.

It should be noted that when chicks are reared on hardware cloth, e.g., in battery brooders, about 0.5 to 1.0 per cent of the chicks may develop a condition of the hock joints that resemble perosis, even though the diet contains adequate quantities of all known-to-be essential nutrients. The development of this condition is believed to be the result of injuries to the hock joint or the result of severe strain on that joint.

It has been reported that perosis may be produced by the feeding of high levels (0.5%) of thiouracil.

Deficiency of Iodine

Only a few cases of goiter, or enlarged thyroid, in chickens have been reported. This condition, however,

very probably is more common in certain sections of the country than is generally realized. Undoubtedly the reason that only a few cases have been reported is that enlarged thyroids are not readily observable in the chickens. Moreover, goiter does not appear to affect the health of chickens seriously or to be a cause of heavy mortality. It should be noted, however, that a deficiency of iodine is one cause of a lower-than-normal metabolism.

Goiter has been produced experimentally by feeding diets of extremely low iodine content (0.025 parts per million parts of feed) to laying hens. Chicks hatched from the eggs of these hens had enlarged thyroid glands. These experiments have provided definite evidence that the chicken requires a small quantity of iodine, but neither the minimum nor the optimum requirement is known. As previously stated, however, the available evidence indicates that the allowance of iodine should be between 2 and 5 PPM (parts per million parts of feed).

Anemia: Deficiencies of Iron and Copper

Anemia rarely occurs among chickens on practical diets, but it has been demonstrated that it can be produced in young chicks by feeding diets extremely deficient in iron or copper or both. In ruminants a small quantity of cobalt, as well as of iron and copper, is necessary for the prevention of a certain type of anemia. It is not improbable that the chicken also requires a small quantity of cobalt. In any case, it has been demonstrated that polycythemia (increase in number of red blood cells) may be produced in ducks by administering small quantities of cobalt.

Anemia may also be produced in young chicks by feeding diets that are deficient in folic acid or pyridoxine or both.

Deficiency of Magnesium

Magnesium deficiency does not occur in chickens raised on practical diets. However, it is necessary to provide a small quantity of magnesium in highly purified diets used in studies of nutritional deficiencies and nutritional requirements. If the diet does not contain enough magnesium, the chicks stop growing and become listless. After a time on such a diet, the chicks have convulsions often followed by coma and, eventually, by death.

Fluorine Poisoning

Although the tolerance of chickens for fluorine is greater than that of cattle and swine, the continued ingestion of diets containing appreciable quantities tends to depress the rate of growth and the production of eggs. Fluorine is distributed almost universally in plants and feedstuffs, as well as in animal tissues, but the quantity present is usually very small. Danger of fluorine toxicosis, or poisoning, in chickens, exists only when the drinking water contains 2 parts per million or more of fluorine or when rock phosphate or phosphatic limestone is included in the diet. Apparently the only observable effects of fluorine poisoning are those it has on growth and egg production.

The available evidence indicates that if the diet contains more than 0.036 per cent of fluorine, from either calcium fluoride or rock phosphate, feed consumption and growth are decreased in proportion to the fluorine content of the diet. There is some evidence, however, that as much as 0.068 per cent of fluorine in the form of the relatively insoluble sodium fluoride may be tolerated.

Selenium Poisoning

Nearly all our knowledge of selenium poisoning in poultry has resulted from studies conducted at the

South Dakota Agricultural Experiment Station. It should be pointed out, however, that South Dakota is not the only State in which selenium poisoning may be encountered. Selenium has been found in the soils and vegetation of at least 11 of the States in the Great Plains and the Rocky Mountains, and it probably is present in the soils of other States in those regions.

Workers at the South Dakota Agricultural Experiment Station found that if laying chickens were fed diets that contained grain in which the selenium content was about 15 parts per million, feed consumption decreased appreciably, the chickens lost weight, and after about a week none of their eggs would hatch. Also, it was observed that, if chicks were fed a diet that contains 65 per cent of toxic (selenium containing) grain, their growth was definitely inhibited and their feathers became ruffled. The egg production of pullets raised on such diets was both delayed and reduced.

It was found that if the diet of laying chickens contained only 2½ part per million of selenium, hatchability was not affected; if the diet contained about 5 parts per million of selenium, however, hatchability was reduced somewhat; and if the diet contained 10 parts per million of selenium, hatchability soon decreased to zero. The decrease in hatchability was attributed to abnormal development of the embryos, most of which died before the twenty-first day of incubation. The most prominent deformity among the abnormal embryos was the lack of a full-sized upper beak. Other abnormalities were the absence of eyes, feet, and wings, wiry down, and edema of the head and neck.

Gizzard Erosion

Several different kinds of gizzard erosion are found in chickens, and the meager evidence available suggests

that they are the result of different causes or combinations of causes. The kind most frequently encountered is preceded by hemorrhages from the glandular layer of the gizzard, which originate from the capillaries in the submucosa. A second kind, which is less common, is characterized by a softening and a pronounced thickening of the lining of the gizzard. In a third kind, which is of still less frequent occurrence, the lining softens and separates completely from the glandular layer.

Little or nothing is known about the development of the second and third kinds of gizzard erosion, but studies made by the writer and associates at the Beltsville Research Center have yielded some information regarding the development of the first kind.

It was found that the erosions are formed as follows: At one or more places in the glandular layer of the gizzard there is a seepage of blood into the secretion from which the lining is formed, and the lining is thus weakened in these places and loses some of its coherence. Reddish brown stains in the lining, varying in size from a mere speck to several square centimeters, are evidence of such seepage. If the passage of blood into the secretion stops at this stage, the subsequent secretion yields a normal layer of lining under the affected area. After a short time threadlike, shallow fissures appear on the inner, or attrition, surface of the lining in such places.

Sometimes the initial seepage of blood is followed by a pronounced hemorrhage, and blood clots form between the weakened lining and the glandular layer. If the seepage continues for some time before the hemorrhage occurs, a fairly thick but deeply stained lining may be found over the blood clot; but if the hemorrhage follows promptly after the initial seepage, only a thin lining or no lining at all is found over the site

of the hemorrhage. In either case, the affected portion of the lining lacks the backing, or support, of the glandular layer and soon cracks or sloughs off. The final result is the formation of deeply fissured areas, holes in the lining, or both. Apparently, when the hemorrhages are large the secreting activity of the glands is markedly reduced or even stopped. In any case, new lining is not formed and large eroded areas appear.

If at any stage in the development of gizzard erosions a suitable diet is fed, the hemorrhages stop, and after 2 or 3 weeks a lining of normal appearance may be formed.

Gizzard erosion has been found in all sections of the country and presumably in all breeds of chickens. Its incidence is greatest in very young chicks and decreases with increasing age.

Apparently gizzard erosion has no appreciable effect on the rate of growth or health of chickens. In any case, its occurrence in very young chicks is not a cause for concern. If it is found in chicks older than 4 weeks, however, the diet probably is not entirely satisfactory.

Various feedstuffs and other materials have been reported to be of value in *clearing up* gizzard erosion. Among those reputed to be of special value are dried ox bile, cholic acid, kale, hempseed meal, alfalfa products, wheat bran, wheat middlings, oats, soybean meal, pig liver and kidney, lung tissue, cartilage, and chondroitin. Of these materials the most effective are dried ox bile and cholic acid.

The diverse nature of the materials just mentioned strongly suggests that gizzard erosion may result from a deficiency of more than one nutritional factor and that the deficiency may be single or multiple. This suggestion is strengthened by the fact that although dried

ox bile has been very effective in the experiments of all workers who have tested it, some workers have failed to get a response from cartilage and chondroitin, and others have obtained very little if any response from alfalfa.

Other Diseases of Nutritional Origin

Several poultry-nutrition workers, while studying the effects of feeding simplified diets to chickens have encountered various abnormal conditions that apparently could not have been caused by a deficiency of any known nutritional factor. However, the very fact that simplified diets were being fed suggests that the abnormal conditions were of nutritional origin. Among such conditions are enteritis (intestinal inflammation), paralysis, arthritis, dermatosis, and fatty liver. Some of these conditions, for example, enteritis, dermatosis, and fatty liver, have been observed even when more or less practical diets were fed.

Enteritis.—Inflammation of the intestine—chiefly of the small intestine—is frequently observed in chickens that are raised without access to the soil and green growing plants. On autopsy, the intestine is often found to be filled with bits of shavings, straw, or other material that had been used as litter; sometimes large quantities of grit are also found. Attempts to demonstrate that the enteritis is caused by a microorganism or other causative agent have failed.

Paralysis.—As has been pointed out in preceding pages, a deficiency of vitamin E in the diet of the young growing chicken produces lesions in the brain; of pantothenic acid, in the spinal cord; of riboflavin, in the main peripheral nerve trunks; of vitamin A, in the central and peripheral nervous systems. Moreover, a deficiency of thiamine produces a toxicosis, or poisoning, of the nervous system. Accordingly, a deficiency of

one or more of these vitamins may produce paralysis or a similar condition.

Paralysis, presumably of nutritional origin, has been observed, however, when adequate quantities of all five of the vitamins just mentioned were supplied. In some instances the supplemental feeding of alfalfa, and in other instances the feeding of large quantities of dried brain, cartilage, wheat middlings, yellow corn, or wheat, prevented the development of the paralysis.

Arthritis.—A condition described as arthritis has been reported to have been produced by the feeding of simplified diets containing highly purified casein. The first symptoms appeared when the chicks were about 3 weeks old. At first the chicks were merely less active than usual, but within a few days they showed very little inclination to walk. When they did walk their gait was decidedly stilted, and there was practically no flexion of the tibiotarsal joints. Often the capsule of the joint was swollen and there was a slight excess of fluid in the cavity.

Dermatosis.—From time to time a dermatosis similar to that produced by a deficiency of pantothenic acid or a deficiency of biotin is observed in growing chicks that are receiving supposedly adequate diets. This condition often disappears if a complete change of diet is made, but is not cured by adding rich sources of pantothenic acid to the original diet.

Fatty livers.—Fatty livers have been observed in young growing chickens, both when a simplified diet was fed and when a practical diet was fed. None of the known vitamins, including choline, was effective in preventing the condition. It appears that fatty liver in chickens may be the result of a number of causes and not necessarily of a single, specific nutritional deficiency. When fatty liver is found, however, it may be concluded that the diet is unsatisfactory, as a result of

either of one or more deficiencies or of an imbalance of certain nutrients.

Feather Picking and Cannibalism

Cannibalism is a term used by some poultrymen in referring to the habit sometimes developed by chickens, other poultry, and game birds of picking one another's feathers, toes, beaks, heads, combs, backs, vents, and other parts of the body. Most poultrymen, however, restrict the use of this term to cases in which blood is drawn. Inasmuch as there are many instances in which only the feathers are picked, or pulled, it is desirable to distinguish between feather picking and cannibalism.

Often the only result of feather picking is that some of the chickens lose many of their feathers, but cannibalism nearly always leads to heavy losses through death. In flocks of pullets just starting to lay, cannibalism generally follows a case of prolapsus of the oviduct; in such cases a number of chickens may become disemboweled, and rather heavy losses may result. Cannibalism among chicks often appears first in the form of toe picking, back picking, or wing picking; once established, it spreads rapidly through the flock.

Although there is evidence that feather picking and cannibalism are the result, in part, of unsatisfactory diets, there often are other contributing causes, such as overcrowding and overheating—especially in the case of chicks in battery brooders. The exact nature of the nutritional deficiency or deficiencies involved is not known, but it has been found that feather picking and cannibalism are less likely to occur if the diet contains about 20 per cent of barley or oats or about 30 per cent of bran and middlings.

It has been reported by several poultry-nutrition workers that feather picking and cannibalism may be

controlled by using ruby-colored lights in place of ordinary lights in battery brooders and brooder houses. It also has been reported that if oats are fed as the sole grain in diets for growing and laying pullets, cannibalism is significantly reduced. It has been suggested that the effective parts of the oats is the hulls. In any case there is evidence that feather picking and cannibalism are likely to appear if diets of very low fiber content are fed.

A fairly effective method of stopping feather picking and cannibalism is to increase the salt content of the diet for 1 or 2 days. If an all-mash diet is being fed, add 2 per cent of salt; but if both mash and grain are being fed, add 4 per cent of salt to the mash. Usually the feather picking or cannibalism stops within a few hours, but in some cases 2 days may be required. *It is not desirable to feed high salt diets for more than 2 days.*

An alternate form of the salt treatment is to place the extra salt in the drinking water. A suitable quantity is about one heaping tablespoonful per gallon of water. The salty water should not be kept before the chickens more than one-half day at a time; it is suggested that they be given the salty water in the morning and plain water in the afternoon. Often, a single half day is enough. If this form of the salt treatment is not effective after the third half day, there is no point in continuing it.

It should be noted that the salt treatment is recommended only as a curative treatment and not as a preventive measure.

If the salt treatment is not effective after 1 to 2 days, it may be necessary to trim or sear back to the quick the upper mandible of the beaks of all the birds. The trimming may be done with a sharp knife, the searing with a hot soldering iron or an electric "de-

beaker." When carefully done, the trimming of the upper mandible is painless. Ordinarily, only about three-sixteenths on an inch of the tip of the beak is removed; the proper amount can be judged readily by the appearance of the beak substance.

Egg Eating

Egg eating is a vice that quickly develops when the chickens do not get enough calcium. The development of the vice appears to be greatly stimulated if there is overcrowding. Also, it has been observed that egg eating is likely to develop when the the diet does not contain enough vitamin D.

NUTRITIVE PROPERTIES OF FEEDSTUFFS

In the economical feeding of chickens the feedstuffs should be chosen so as to supply all the required nutrients in adequate quantities, but as cheaply as possible. Often the cost of the feed may be appreciably reduced by the simple substitution of one feedstuff for another; there are times, however, when a feedstuff can be replaced only by a combination of two or more feedstuffs.

That no feed manufacturer or poultryman need be a slave of this or that ingredient or of several ingredients was forcibly demonstrated during World War II. It was learned, through the necessity of making changes and substitutions, that if some particular ingredient is not available, another one or combination of several can be used in its place. Among the things that were demonstrated were: Although milk by-products are excellent feedstuffs, they are not indispensable; the high-quality protein and water-soluble vitamins of milk may be obtained from other sources. Animal protein is not essential; soybean meal may be used as the chief source of protein; dried cow manure contains one or more factors that enable soybean meal to replace the animal-protein feedstuffs; and, moreover, the so-called animal protein factor is found in at least a few feedstuffs not of animal origin. Chickens easily tolerate diets that contain much more than 4 to 5 per cent of crude fiber; diets containing as much as 11 per cent of crude fiber were fed successfully. Corn is not essential; corn, milo, barley, wheat, and oats are interchangeable, if the diet is properly adjusted after a change of grain is made. Cod-liver oil is not indispensable; there is a varied assortment of feeding oils

to take its place. Even the feeding oils are not indispensable; dehydrated alfalfa meal may be used as a source of vitamin A, and D-activated (irradiated) animal sterol may be used as a source of vitamin D. In short, no feedstuff is indispensable.

When changes and substitutions are made, however, the resulting diet should be checked carefully to find out whether or not it contains enough of all the necessary nutrients, especially protein, minerals, and vitamins. The tables at the end of this book will aid materially in making changes and substitutions; they are of value also in formulating new feed mixtures.

Palatability

Although one feedstuff may have essentially the same nutritive value as another, it may not be so palatable. This should be kept in mind because a reduction of feed consumption will usually result in a slower rate of growth or a decreased production of eggs. Fortunately, however, taste and smell are poorly developed senses in the chicken, and palatability is largely dependent on the physical properties of the feed. Thus, sight and touch play important roles. Memory may also be an important factor because a feedstuff, or a formula feed, that once has caused digestive disturbances or discomfort usually will not be eaten with relish a second time.

Finely ground or sticky feeds are not palatible. When a chicken is offered a choice of several feedstuffs, those that are finely ground and those that form a sticky mass and are swallowed with difficulty usually are not selected. For example, chickens will not readily eat finely ground alfalfa meal, but will eat with relish the leaves from alfalfa hay. A granular, loose-textured mixture of feedstuffs is nearly always quite palatable and, therefore, is to be preferred.

Even though the chicken has poorly developed senses of smell and taste, it appears to be able to distinguish between fresh and stale feed. In any case, if given a choice between fresh and stale feed, it almost invariably will select the former. Moreover, in at least most instances, a formula feed that is more than a few months old is likely to be deficient in vitamin A and vitamin D. For that reason, one should not buy or mix more chick starting feed or growing feed than will be used in the current season. In no case should formula feed be kept over from one season to the next.

Specific Properties

The feedstuffs in any diet for chickens are usually chosen—or should be chosen—on the basis of their ability to serve economically as sources of one or more specific nutrients. Thus, the cereal grains are chosen as sources of readily digestible carbohydrates, but preference is sometimes given to yellow corn because it is also a fair source of vitamin A. Dehydrated alfalfa meal is often used primarily because it is an excellent source of vitamin A; however, it is also a very good source of riboflavin, vitamin E, and pantothenic acid. Dried skim milk is one of the best sources of pantothenic acid and is a very good source of riboflavin and protein of excellent quality. Meat scrap and fish meal, in addition to being good sources of animal protein—and of the so-called animal protein factor—supply fairly large quantities of calcium and phosphorus. Bran and middlings are sources of many of the water-soluble vitamins and vitaminlike factors, fiber of suitable kind, miscellaneous minerals (including comparatively large quantities of manganese), and protein of fair quality. Dried distillers' solubles and other fermentation products and byproducts are excellent sources of riboflavin as well as other vitamins of the B-complex.

And, finally, the feeding oils (sometimes called A and D oils), are usually included in the diet as a source of vitamin D, but may serve to supply a goodly portion of the vitamin A and be of value in reducing the dustiness of the feed.

Quality of the Protein

Unless the protein in the diet supplies adequate quantities of all the amino acids that the chicken is unable to synthesize—or synthesize at a sufficiently rapid rate—growth and egg production will be limited in proportion to the inadequacy of any one of these compounds. When the protein in a feed mixture supplies adequate quantities of all the amino acids that the chicken is unable to synthesize, it may be described as protein of good quality.

Usually, but not always, it is necessary to use one or more feedstuffs of animal origin to obtain a feed mixture in which the protein is of good quality. In any case, many of the feedstuffs of animal origin appear to contain more of the so-called "animal protein factor" than feedstuffs of plant origin. For this reason, at least until more is known about the "animal protein factor," it is a good practice to formulate feed mixtures so that not less than 10 per cent of the total protein is derived from feedstuffs of animal origin.

Tables that give the average amino acids content of a number of feedstuffs are given at the end of this book. These tables may be used as an aid in formulating feed mixtures that will contain adequate quantities of all the amino acids the chicken is unable to synthesize. If a given feedstuff does not contain the quantity of protein shown in these tables, an approximation of its amino acid composition may be obtained as follows: Divide the percentage of each amino acid given in the tables by the percentage of protein shown and multiply

by the percentage of protein actually present in the feedstuff. For example, if one desires to find out how much arginine there is in a sample of oats that contains 13 per cent of protein, he divides the percentage of arginine shown in the table by the percentage of protein shown and multiplies by 13. Thus, oats that contain 13 per cent of protein contain approximately (0.55/11)13 or 0.65 per cent of arginine. In a like manner it is found that the approximate quantity of tryptophane in oats that contains 13 per cent of protein is (0.11/11)13 or 0.13 per cent.

Total Digestible Nutrients

Due to the fact that in the chicken the urine and feces are excreted together, considerable difficulty is experienced in determining the digestibility of the various feedstuffs in this species. In much of the work that has been done on digestibility in the chicken, methods which are not fully dependable for protein have been used and some of the data so obtained are rather variable. Gradually there has accumulated, however, a fairly large body of reasonably reliable data on the digestibility of a number of feedstuffs used in feeding chickens. Selected data on the digestibility of feedstuffs are given in a table at the end of this book.

In general, digestibility data have not been used very much by poultry nutrition workers. However, when properly used, such data are of value in developing diets that have a high content of total digestible nutrients and are particularly suitable for the production of poultry meat and eggs. Also, such data are of value in indicating which of several feedstuffs is likely to give the best results when substituted for another.

In using the data on total digestible nutrients, it should be remembered that the content of total digestible nutrients in a given feedstuff depends on the

composition of that feedstuff. Accordingly, when the actual composition of a feedstuff is known to be different from the average composition, the percentage of total digestible nutrients should be recalculated before it is used. However, in the absence of definite information about the composition of a feedstuff, the percentage of total digestible nutrients given in the table may be used.

As an example of the application of data on total digestible nutrients, we may consider the desirability of substituting milo for yellow corn in a diet in which the adequacy of the vitamin A is not dependent on the yellow corn. Inspection of the data in the last column of the table shows that both milo and corn supply the same quantity of total digestible nutrients. If, under the conditions stated, milo is cheaper than corn, it would be more economical to use it than to continue using corn. On the other hand it would not be economical to substitute wheat for corn unless the wheat were appreciably cheaper than the corn. However, inasmuch as some feedstuffs are included in the diet because they possess certain specific properties, it is clear that the quantity of total digestible nutrients cannot be used as the sole criterion in deciding whether or not a proposed substitution should be made.

Relative Value of the Common Cereal Grains

A number of experiments have been conducted in which the common cereal grains have been compared with one another, when they were fed at the same level in otherwise identical diets. The data so obtained indicate that but little difference is to be expected in the gains of growing chicks regardless of which of the cereal grains is used. However, oatmeal is somewhat more efficient in producing gains in live weight than is corn, wheat, barley, or whole oats.

For laying hens, corn appears to be slightly superior, and oats slightly inferior to barley and wheat. On the basis of the gains produced in cage-fattened chickens there is little or no difference between diets containing equal quantities of corn, wheat, oats, or barley; but diets containing oats are not so efficiently utilized as are diets containing the other three grains. There is some evidence, however, that the flesh of chickens receiving corn or barley is superior in flavor to that of those receiving wheat or oats.

The grain sorghums.—The available information about the grain sorghums in the feeding of poultry indicates that they are equal to corn in nutritive value. In general, however, the grain sorghums contain on the average considerably less than 50 per cent as much vitamin A activity as yellow corn. The riboflavin content of the several grain sorghums varies from 0.5 to 0.9 milligram per pound and averages about the same as, or slightly higher than, corn. The pantothenic acid content and the niacin content, especially the latter, of the several grain sorghums are higher than those of corn.

METABOLIC ANTAGONISTS AND INCOMPATIBILITIES IN FORMULA FEEDS

Since the first edition of this book was published (1941) much has been learned about the existence of substances that antagonize or inhibit the action of nutrients, hormones, and enzymes. There has been, also, an increase in our knowledge of factors and conditions that accelerate the destruction of nutrients, as well as in our knowledge of incompatabilities in formula feeds.

One important development has been the recognition of the fact that certain chemical (structural) analogues of certain nutrients interfere with the utilization of those nutrients. A good example is the antagonistic action of pyrithiamine and thiamine. It has been shown that symptoms of deficiency of thiamine easily may be produced in mice by feeding pyrithiamine. If, however, the quantity of thiamine in the diet is increased sufficiently, the mice are protected against the action of the pyrithiamine. Still another example is the antagonism between the chemical analogues ethionine and methionine. Ethionine is toxic to rats and causes loss of weight, but this effect of ethionine may be counteracted by feeding additional methionine. As yet, there appears to have been no demonstration of this particular type of metabolic antagonism, i.e., analogue antagonism, in the chicken, but it is not unlikely that such demonstrations will be made.

Dr. John C. Hammond, a former colleague of the writer at the Beltsville Research Center, was one of the first, if not the first, to point out the importance, in practical animal nutrition, of a number of "incompatabilities" in formula feeds (*Feedstuffs* 14 (48) : 29-

33; 1942). It now is widely recognized that there are many factors that affect the utilization of the several nutrients, either by analogue antagonism, inhibition of utilization, or actual destruction.

Factors Affecting the Activity of the Vitamins

Vitamin A.—As yet, no analogue antagonist of vitamin A has been reported. It has been demonstrated, however, that an excess of vitamin A in the feed of chickens inhibits the deposition of pigment (xanthophyll) in the shanks, skin, and egg yolk. Carotene appears not to have this effect.

Vitamin A and carotene are both destroyed by oxidation; and the oxidation of these two substances is catalyzed by the lipoxidase naturally present in a number of feedstuffs. It has been demonstrated that the carotene in alfalfa, for example, may be conserved by the destruction or inactivation of the lipoxidase in that feedstuff. On the other hand, fine grinding of alfalfa meal accelerates the destruction of carotene.

Certain lots—but not all lots—of meat scrap, fish meal, and some other feedstuffs cause the destruction of vitamin A and carotene. Vitamin A activity in feedstuffs is readily destroyed by intimate contact with charcoal, rancid fats, and salts of manganese, iron, and copper. In general, the destruction of vitamin A activity is more rapid at high temperatures than at low temperatures.

Vitamin D.—No analogue antagonist of vitamin D has been reported. Elemental sulphur (e.g., flowers of sulphur and colloidal sulphur) interferes with the absorption of vitamin D from the intestine. Mineral oil also interferes with the absorption of vitamin D. Rickets in the growing chicken may be produced by including enough sulphur or mineral oil in a diet that

otherwise contains a fully adequate quantity of vitamin D.

Vitamin D is readily destroyed by oxidation when in intimate contact with such diverse materials as bone meal, oystershell, calcium carbonate, sand, dried whey, dried skim milk, and milk sugar.

Vitamins E.—Alpha-tocoopherol quinone is an analogue antagonist of alpha tocopherol (vitamin E). This case of metabolic antagonism is different from the usual case, in that (at least in the pregnant rat) vitamin K and not vitamin E counteracts the effects of the alpha-tocopherol quinone.

When diets containing large quantities of cod-liver oil (3 per cent or more) are fed to young chicks, very little pigment is deposited in the shanks and skin, and in some cases encephalomalacia develops. The administration of vitamin E will prevent or cure the encephalomalacia but does not enable pigment to be deposited in the shanks and skin.

Vitamin K.—Among the antagonists of vitamin K that have been reported are dicumarol (found in spoiled sweet clover hay), 2,4-dichloro-naphthaquinone, certain sulfonamides, and the salicylates (e.g., aspirin).

An excess of cod-liver oil decreases the apparent activity of vitamin K. Charcoal, when in intimate contact with vitamin K, tends to destroy it.

Ascorbic acid.—Glucoascorbic acid, which is similar in structure to ascorbic acid but contains an additional HCOH group, inhibits the action of ascorbic acid. Both chickens and rats normally do not become scorbutic when fed diets that contain no ascorbic acid. Rats, however, become scorbutic if enough glucoascorbic acid is added to their diet. It is not unlikely that scurvy could be produced in chickens in the same way.

Thiamine.—There probably are several analogue antagonists of thiamine; two, pyrithiamine and oxythia-

mine, have been reported. Raw fish of certain species (e.g., carp) contain an enzyme that destroys thiamine.

Fat is reported to have a sparing action on thiamine.

Riboflavin.—A number of analogue antagonists of riboflavin are possible. Among those that have been reported are (1) iso-riboflavin, which differs from riboflavin in the positions of the two methyl groups, (2) the dichloro analogue, which contains chlorine in the positions occupied by methyl groups in riboflavin, and (3) the dihydrophenazine analogue.

An excess of fat in the diet seems to increase the requirement of riboflavin. Riboflavin is destroyed by intimate contact with charcoal.

Pantothenic acid.—There are two known inhibitors of pantothenic acid, i.e., thiopanic acid (or pantoyltaurine) and phenylpantothenone. As yet, the symptoms of deficiency of pantothenic acid have not been produced in animals by feeding these inhibitors. The antagonism of these compounds toward pantothenic acid has been demonstrated by the use of microorganisms.

Para-aminobenzoic acid.—One of the first analogue antagonists to be recognized as such was sulfanilamide; it and other sulfonamides are antagonists of para-aminobenzoic acid in cultures of certain micro-organisms.

Niacin.—Two analogue antagonists of niacin have been reported; these are 3-acetylpyridine and 3-pyridine sulfonic acid.

In the chick, as in the rat, the niacin requirement is increased by including large quantities of corn in the diet. This effect of corn, however, may be nullified by adding a sufficient quantity of tryptophane to the diet.

Biotin.—Among the analogue antagonists of biotin are desthiobiotin, biotin sulfone, and imidazilidone caproic acid.

Avidin, a protein compound found in raw egg white and secretions of the oviduct, inactivates biotin by forming a stable complex with it. Deficiency of biotin is easily produced in growing chickens by feeding raw egg white.

Choline.—The triethyl analogue of choline is antagonistic to choline in certain of its functions in the animal organism.

Miscellaneous Antagonisms and Inhibitions

Amino acids.—The antagonism of ethionine and methionine already has been referred to. In the case of certain yeasts and bacteria, beta-2-thienylalanine is an antagonist of phenylalanine. Also, d-leucine is an antagonist of l-leucine, and d-valine of l-valine, in the case of certain micro-organisms.

Instances have been reported in which even two naturally occurring amino acids are in a sense antagonistic in the case of micro-organisms. One such instance involves arginine and lysine. Another instance involves the growth-inhibiting effect of tryptophane, which is nullified by its analogue phenylalanine.

Minerals.—Iron and other elements that form highly insoluble phosphates (e.g., manganese) are able to produce rickets in animals if fed in sufficiently large quantities: Phosphorus, when present in the feed in the form of phytin is only partially available for the formation of bone.

The presence of oxalic acid in feedstuffs decreases the availability of calcium.

Salts of manganese, iron, and copper cause losses of iodine from potassium iodide, unless the latter is suitably stabilized. The feeding of soybean meal to chicks has been reported to increase their iodine requirement.

Sulphur not only interferes with the absorption of vitamin D—as previously stated—but it also interferes with the deposition of pigment in the shanks and skin of chickens. Deposition of pigment in the shanks and skin is interfered with also by meat scrap, fish meal, soybean meal, fish oils, manganese sulphate, and mineral oil.

Charcoal, in addition to having a destructive action on vitamin A, riboflavin, and vitamin K, appears to have a similar effect on the gizzard factor.

Other antagonisms.—Linseed meal contains glucosides which, under certain conditions, liberate hydrocyanic acid, which in turn inhibits the functioning of many enzyme systems. This undesirable property of linseed meal may be destroyed by boiling, treatment with steam, or by soaking and incubating at a suitable tempearture. The latter treatment also increases the nutritive value of linseed meal.

There is an antitryptic factor in soybean meal that interferes with the digestion of the protein in that feedstuff.

Tributyrin is "toxic," presumably because, as an analogue antagonist of one or more of the other glycerides it interferes with the normal metabolism of fat.

Wheat, rye, legumes, buckwheat, cottonseed meal, and other feedstuffs, as well as meat scrap, fish meal, dried skim milk, corn, eggs, soybean meal, and linseed meal, have all been reported to contain substances that are antagonistic or inhibitory in one species of animal or another.

INDIVIDUAL FEEDSTUFFS

In selecting the ingredients of a diet or formula feed, it is desirable to have as much information as possible about the individual feedstuffs. Useful information about the proximate chemical composition, the amino acid content, the mineral content, the vitamin content, and the digestibility of a number of feedstuffs used in the feeding of chickens is given in the tables at the end of this book. Additional information about a number of selected feedstuffs is given in the paragraphs that follow.

Grain and Seeds, and Their Byproducts

Wheat, corn, barley, oats, rye, and the grain sorghums, when shipped in interstate commerce, must be inspected and graded according to the official grain standards of the United States. In buying grain for the feeding of chickens, poultrymen and feed manufacturers should take advantage of this fact and buy according to grade. It is not sufficient to ask for just corn, oats, or any other grain for which standards have been established, the grade should be specified in order to obtain the quality desired.

In general, the chief criterion is the number of pounds per bushel; in the case of corn and the grain sorghums, the moisture content is also an important factor; and in the case of barley and oats, the percentage of sound cultivated barley or oats is also used in determining grade.*

*The reader is referred for further details to the Handbook of Official Grain Standards of the United States. (For sale by the Superintendent of Documents, Government Printing Office, Washington 25, D. C.)

The grades of wheat are Nos. 1 Heavy, 1, 2, 3, 4, 5, and Sample grade. Grade No. 1 Heavy of Hard Red Spring Wheat and Grade 1 of the other classes of wheat must weigh 60 pounds per bushel; Grade 1 of Hard Red Spring Wheat and Grade 2 of the other classes need weigh only 58 pounds per bushel; and Grade 5, except in the case of Hard Red Spring Wheat, must weigh 51 pounds per bushel. Grade 5 of Hard Red Spring Wheat need weigh only 50 pounds per bushel. As the grade number increases, the number of pounds per bushel decreases. For feeding chickens any of the grades above Sample grade may be used, but usually, from the standpoints of quality and price, Grade 3 or Grade 4 is to be preferred.

The grades of corn are Nos. 1, 2, 3, 4, 5, and Sample grade; the corresponding minimum weights per bushel are 54, 53, 51, 48, and 44 pounds, respectively, for the first five grades; and the corresponding maximum limits of moisture content are 14.0, 15.5, 17.5, 20.0, and 23 per cent, respectively. For feeding chickens the first three grades are to be preferred. During the warmer months of the year Grade 1 or Grade 2 should be chosen if the corn must be ground and stored for a few weeks before it is used, because these two grades—especially Grade 1—are less likely to heat and spoil than those of greater moisture content. During the cooler months Grade 3 usually is satisfactory.

Barley has the same number of grades as corn. The minimum weights per bushel are 47, 46, 43, 40, and 35 pounds, respectively, for the first five grades; and the corresponding minimum limits of sound barley are 95, 93, 90, 80, and 70 per cent, respectively, of the total. The first three grades are always to be preferred.

There are five grades of oats, including Sample grade. The minimum weights per bushel are 32, 30, 27, and 24 pounds, respectively, for the first four grades; and the corresponding minimum limits of sound oats are

97, 94, 90, and 80 per cent, respectively, of the total. There are also several special grades, among which are (1) tough oats which, regardless of weight per bushel, contain more than 14.5 per cent but not more than 16 per cent of moisture; (2) heavy oats which weigh between 35 and 38 pounds per bushels; and (3) extra heavy oats which weigh 38 pounds or more per bushel. The extra heavy or heavy special grades are to be preferred for feeding chickens; tough oats are not satisfactory.

The grade specifications for rye are not given because this grain is not particularly suitable for feeding chickens and usually is used only in emergencies.

There are five grades of grain sorghums, including Sample grade. The minimum weights per bushel are 55, 53, 51, and 49 pounds, respectively, for the first four grades; and the corresponding maximum limits of moisture are 14, 15, 16, and 18 per cent, respectively. The first three grades are to be preferred for feeding chickens.

Definitions of the many commercial feedstuffs and ingredients of formula feeds that normally are available in the United States are published annually in "Official Publication: Association of American Feed Control Officials, Incorporated." In recent years this publication has contained the more pertinent official and "tentative" methods of analysis of the Association of Official Agricultural Chemists.

Barley.—This grain, if the proper grades are used, is an excellent feedstuff for poultry and is used extensively in those sections of the country in which it is cheaper than corn. It is not so palatable as corn, wheat, or oats unless it is fed from an early age. It ranks well with corn as an ingredient of finishing (so-called "fleshing") diets. Some poultrymen believe that better feather growth is obtained by feeding barley than by

feeding corn, and that it is of some value in preventing cannibalism. When used in mashes it should be finely and evenly ground.

Corn.—Corn is widely used in the United States in the feeding of poultry. It is palatable and readily digested; it has a low content of crude fiber and supplies a larger quantity of total digestible nutrients, per pound, than most other feedstuffs commonly used in the feeding of poultry. Yellow corn generally is preferred to white corn because the former is a fair source of vitamin A activity whereas the latter contains almost none. Old corn is not so desirable as new corn of proper moisture content. If stored for a long time—a year or more—yellow corn tends to lose 30 per cent or more of its vitamin A activity. When used in laying mashes, corn should be coarsely but evenly ground; in mashes for young chicks it may be somewhat more finely ground. Argentine (flint) corn has essentially the same nutritive value as the native dent corn and is just as suitable for feeding chickens.

Corn gluten feed.—This feedstuff varies considerably in composition. In general, however, it is a fairly good source of protein and total digestible nutrients, even though it contains on the average about 7.5 per cent of crude fiber. When made from yellow corn, as is usually the case, it contains a worthwhile quantity of vitamin A. It is a good source of vitamin E and niacin, and supplies appreciable quantities of riboflavin and pantothenic acid.

Corn gluten meal.—This is the part of the corn that remains after the larger part of the starch, germ, and bran is removed in the manufacture of corn starch or corn syrup. Sometimes it contains some corn oil-cake meal or corn solubles, or both. If made from yellow corn, it is a very good source of vitamin A. It is one of the better sources of methionine*; mixtures of it and

soybean meal are usually better sources of the required amino acids than is either soybean meal or corn gluten meal alone. It is reported to be of special value as a protein supplement to cereal grain mixtures intended to be fed to growing chicks, when liquid skim milk is used as the sole source of animal protein.

Cottonseed meal.—Because of its undesirable effects on the color of the yolks of the eggs, cottonseed meal is not used very much in feeding laying chickens. However, for growing chicks it is a fairly good protein supplement. It has a fairly high content of arginine and lysine and of the other four amino acids most likely not to be present in sufficient quantities in the feed of growing chickens.

Distillers' dark grains, dried.—Although this feedstuff contains about 28 per cent of protein, the quality of the protein is not of particularly good quality and the protein, itself, is low in tryptophane. However, this feedstuff is a good source of riboflavin, a fair source of pantothenic acid, and a very good source of choline and niacin.

Linseed meal.—This feedstuff is not used very much in feeding chickens because it contains a "toxic" substance. However, the toxicity can be removed by steaming and by other treatments. Its chief value lies in the fact that in its passage through the alimentary tract it absorbs a fairly large quantity of water and tends to form a somewhat bulky, mucilaginous mass which aids in the passage of feed residues through the intestines and tends to yield a coherent fecal mass. It is a rather good source of tryptophane.

Unless linseed meal has been treated to destroy its toxicity, it should not be used at a level greater than 2 per cent of the total feed intake.

Linseed meal contains small quantities of certain essential fat acids. Some poultrymen believe that it

tends to improve the general appearance of the feathers.

Milo and other grain sorghums.—The grain sorghums are similar to corn in their general nutritive properties, but usually are not so palatable. Yellow milo is generally preferred to the kafirs, the durras, and the other milos. The grain sorghums may be used as a major part of the grain mixture or, when properly ground, to replace other grains in the mash.

Oats and oat meal.—Oats are an excellent and palatable feedstuff for chickens, and are reputed to be of value in preventing cannibalism and feather picking. They are a good source of the gizzard factor. When used in starting mashes, they should be very finely ground; nevertheless whole oats may be fed to chicks after they are a few days old. Nothing is gained by clipping oats that are to be fed to chickens.

Rolled oats and oat groats are highly prized as an ingredient of diets for growing chicks. Both ground oats and oat meal (or groats) are valuable ingredients of finishing diets.

Peanut meal.—Peanut meal is a good source of protein of a type that makes it a good supplement to the cereal grains. It is an excellent source of arginine, a good source of lysine, cystine, tryptophane, and glycine but is inferior to the other plant protein supplements as a source of methionine. It is a fair source of riboflavin, an excellent source of pantothenic acid and niacin, and a good source of choline.

Rice.—Rice is a very palatable and highly digestible cereal, but it is not widely used because of its relatively high cost. When available at a suitable price, it may be used to advantage in feed mixtures for chickens.

Sesame seed meal.—Sesame seed meal is a good protein supplement; it is a better source of arginine, methionine, and tryptophane than soybean meal but a

poorer source of lysine, cystine, and glycine. A mixture of sesame seed meal and soybean meal is a better source of protein than is either one, alone.

Soybeans and soybean meal.—Soybeans are not widely fed to chickens. Soybean meal, however, is now used in practically all poultry mashes as a source of a part—sometimes a major part—of the total protein. It is a rather good source of arginine, an unusually good source of lysine, a fairly good source of methionine and cystine, and a good source of tryptophane and glycine. It is a good source of choline.

Sunflower seed meal.—The protein of sunflower seed meal is of good quality. In proportion to its total protein content it is a better source of arginine and methionine than soybean meal but a poorer source of lysine, cystine, and glycine. It is an excellent source of pantothenic acid and niacin. It has a rather high fiber content, even when made from hulled seeds.

Wheat.—At various times large quantities of wheat have been used in feeding poultry. It is very palatable and is an excellent feedstuff. It supplies only about 90 per cent as much total digestible nutrients as corn, but contains more protein and usually is a somewhat better source of most of the vitamins of the so-called B-complex.

Wheat bran.—This byproduct of the milling of wheat is widely used in feeding all classes of poultry. It has a rather low digestibility and, hence, a low nutritive value. It has an appreciably higher content of riboflavin, pantothenic acid, choline, niacin, and thiamine than wheat. It is reputed to be a good source of the gizzard factor. Although it has a somewhat higher content of most of the required amino acids than wheat, its protein is not so well digested. It has a rather high content of phosphorus, but most of it is not readily available. It is an excellent source of man-

ganese. The value of bran in a poultry feed is, in part, dependent on its physical properties. It supplies bulk and helps to improve the texture and palatability of a mixture of feedstuffs.

Wheat middlings and shorts.—These two by-products of the milling of wheat are very similar in composition. In general, they consist of the finer particles of bran together with a very small quantity of the fibrous offal obtained from the "tail of the mill." They also contain variable quantities of wheat germ. Wheat middlings and shorts are a better source of most of the vitamins of the so-called B-complex than is wheat. They supply more total digestible nutrients than wheat bran. Their value is dependent in part, as is that of bran, on their physical properties. They are widely used in feeding all classes of chickens.

Products of Animal Origin

Beef scrap.—Beef scrap of the best grade is a valuable protein supplement for the feeding of chickens. It is a good source of calcium and phosphorus. Its protein and fat are easily digested.

Dried buttermilk and dried skim milk.—These two products are excellent sources of protein of high quality. In general, dried skim milk is more uniform in composition and quality than is dried buttermilk. Both are good sources of nearly all the mineral elements, excepting iron and manganese. Both are excellent sources of riboflavin and pantothenic acid, but dried buttermilk usually is the better source of these two vitamins.

Fish meal.—There are several different kinds of fish meal. Three different methods are used in drying the materials used in making fish meal and, according to the method used, the resulting products are known as vacuum-dried, steam-dried, and flame-dried fish meals. The best kinds are the vacuum- and steam-dried

meals. Much less flame-dried fish meal is now produced than formerly. In general, fish meal is the best source of high quality protein of the many feedstuffs used in feeding chickens; it is comparatively high in all the required amino acids. Fish meal is a fairly good source of riboflavin and pantothenic acid and a good source of choline and the animal protein factor. It is also a good source of calcium and phosphorus.

Meat scrap and meat-and-bone scrap.—These products are good sources of protein of high quality, but, in general the quality of the protein is not so good as that of fish meal, dried buttermilk, and dried skim milk. They contain appreciable quantities of riboflavin, pantothenic acid, choline, niacin, and the animal protein factor. They are good sources of readily available calcium and phosphorus.

Dried whey.—The protein content of dried whey is much lower than that of dried buttermilk and dried skim milk, but the protein is of almost equally good quality. Dried whey is a very good source of riboflavin and pantothenic acid. It contains a good assortment of the mineral elements found in milk. It is more laxative than either dried buttermilk or dried skim milk.

Green Feeds, etc.

Alfalfa meal.—There are two kinds of alfalfa meal: dehydrated and sun-cured. Within each kind there are several classes: alfalfa leaf meal, alfalfa meal, and alfalfa stem meal.

According to the "Official Publication: Association of American Feed Control Officials, Incorporated," "**Alfalfa Leaf Meal** is the ground product consisting chiefly of leafy material separated from alfalfa hay or meal. It must be reasonably free from other crop plants and weeds and must not contain more than 18 per cent of crude fibre," and "**Alfalfa Meal** is the product ob-

tained from the grinding of the entire alfalfa hay, without the addition of any alfalfa stems, alfalfa straw or foreign material, or the abstraction of leaves. It must be reasonably free from other crop plants and weeds, and must not contain more than 33 per cent of crude fibre."

Modern methods of the manufacture of alfalfa meal, especially dehydrated alfalfa meal, have made these definitions obsolete. Most alfalfa meals are sold on the basis of their protein content, e.g., alfalfa meal (20 per cent), alfalfa meal (17 per cent), and alfalfa meal (13 per cent); and some of them are sold on the basis of their carotene content as well. In a general way, alfalfa meal (20 per cent) is essentially the same as alfalfa leaf meal, and alfalfa meal (17 per cent) is the same as alfalfa meal. Usually alfalfa meal (13 per cent) is not suitable for use in feeding chickens.

Although alfalfa meal (either the one containing 17 per cent of protein or even the one containing 20 per cent of protein) supplies less total digestible nutrients than bran, or any other dry feedstuff commonly used in feeding poultry, it is an extremely valuable ingredient of formula feeds for chickens. Its value lies in the fact that it, when properly prepared, is a veritable store-house of the vitamins, contains protein of good quality, and is relatively rich in minerals. It is an excellent source of vitamin A activity (carotene) and vitamin E, a very good source of riboflavin and pantothenic acid, and a good source of niacin, thiamine, choline, vitamin K, and vitamin C.

Whenever possible, alfalfa meal should be purchased on the basis of its vitamin A activity (carotene content).

Carrots.—Yellow carrots are a good source of vitamin A activity (carotene). They may be stored in suitable cellars for use when green feed is scarce.

Distillers' solubles, dried.—Dried distillers' solubles are a good source of riboflavin, pantothenic acid, niacin and thiamine, and an excellent source of choline.

Kale.—Kale is used as a green feed in some sections of the country. It is rated as a good source of vitamin A activity, riboflavin, pantothenic acid, and thiamine.

Molasses.—Molasses is of value in reducing the dustiness of feeds. Cane molasses is a fair source of riboflavin, choline and niacin, and usually a good source of pantothenic acid. Because of its laxative properties it is best to use not more than 2.5 per cent in all-mash (or so-called complete) feeds and not more than 4 per cent in mashes that are to be fed with an approximately equal weight of grain.

Yeast.—Dried brewers' yeast is an excellent source of riboflavin, pantothenic acid, choline, niacin, and thiamine. Its protein is of rather good quality.

Mineral Supplements

Calcium and phosphorus.—The best supplementary sources of calcium are calcite, oystershell, and high-calcium limestone. Crab shell, when properly dried and ground is a good source of calcium, but it is available in only a few sections of the country. When a source of both phosphorus and calcium is required, steamed bone meal and di-calcium phosphate are the products of first choice, but defluorinated phosphate rock or defluorinated superphosphate may be used.

Salt.—Either common salt or iodized salt may be used. It should be finely granular and free flowing. Care always should be taken to break up any lumps that may be present. As has been stated previously, iodized salt contains only 70 PPM of iodine and, therefore, when used at a level of 0.5 per cent will add only 0.35 PPM of iodine. Therefore, iodized salt ordinarily will

supply only 0.35 PPM—or less—of the 2 to 5 PPM that is desired.

Trace minerals.—The most commonly used maganese supplement is feeding grade manganese sulphate that contains 65 per cent of $MnSO_4$. Manganese carbonate may be used if it is soluble in dilute (tenth normal) hydrochloric acid. Some manganese carbonates are insoluble in dilute hydrochloric acid and, therefore, are of no value to the chicken. Inasmuch as it usually is necessary to add only about 20 PPM of manganese to all-mash feeds, 2⅔ ounces of feeding grade manganese sulphate **per ton** of feed is all that is needed. This small quantity is best added in the form of a pre-mix.

Potassium iodide is the most commonly used iodine supplement. Because potassium iodide readily loses its iodine in the presence of air and moisture, it should be suitably stabilized if it is to be included in a poultry feed. One of the best stabilizers is calcium stearate. It usually is necessary to add about 4.5 PPM of iodine to a poultry feed if the total iodine content is to be about 5 PPM. To have an added iodine content of 4.5 PPM in an all-mash feed, it is necessary to add only 0.21 ounce of stabilized potassium iodide (90 per cent KI) to each ton. This quantity is so small that it is absolutely necessary to add it in the form of a pre-mix.

The necessity of adding the trace minerals iron, copper, and cobalt has not been established. However, if one wants to be sure that his feed contains enough of these elements, small quantities may be added. Because, at the most, only very small quantities should be added, it is necessary to use a pre-mix. Only compounds of iron that are soluble in dilute (tenth normal) hydrochloric acid should be used. Most iron oxides are not soluble in dilute hydrochloric acid and, therefore, are of no value as a source of iron to the chicken. Fer-

rous sulphate and ferrous carbonate appear to be the best sources of supplementary iron. As a source of copper, either copper sulphate or copper hydroxide may be used. As a source of cobalt, one may use cobalt carbonate, cobalt sulphate, or cobalt acetate. In view of what is known of the iron and copper requirements of the chicken, there is no point in adding more than 20 PPM of iron and more than 2 to 3 PPM of copper to an all-mash poultry feed. In any case, a truly large excess of iron (e.g., more than 500 PPM) should be avoided. If one adds cobalt, the quantity need not be in excess of 0.2 PPM.

Miscellaneous Materials

Charcoal.—Charcoal is of little or no value in the feeding of chickens. In some instances it may cause the destruction of an appreciable quantity of some of the vitamins.

Grit.—Grit is best classified as calcareous (containing calcium) and non-calcareous (not containing calcium). Other classifications of grit are (a) hard and soft, and (b) soluble and insoluble. Materials used as grit include:

(1) Calcareous grit
- (a) Calcite, or crystalline limestone
- (b) Limestone, amorphous or semi-crystalline
- (c) Oystershell
- (d) Other shell, e.g., clamshell and coquina shell

(2) Non-calcareous grit
- (a) Quartz
- (b) Feldspar
- (c) Granite
- (d) Mica
- (e) Pebbles (largely quartz)
- (f) Gravel (largely quartz)

The usual commercial sizes of grit are:

Small	through # 12 screen,	held by # 20 screen
Medium	through # 8 screen,	held by # 12 screen
Large	through # 5 screen,	held by # 8 screen
Extra Large....	through # 4 screen,	held by # 5 screen

Ordinarily, the best available materials for use as grit are river gravel and native pebbles of suitable size. Crushed quartz, feldspar, granite, and mica are all good materials for use as grit. In general, however, the calcareous grits have an advantage over the non-calcareous grits, in that the former serve two purposes, i.e., they act as a grinding agent and serve as a source of calcium, whereas the latter serve only one purpose, i.e., they act only as a grinding agent. Notwithstanding, some calcareous grits (e.g., amorphous limestone) are too soft to serve as effective grinding agents. (Also, it may be pointed out that some granite grits are too friable to be good grinding agents.) The best of the calcareous grits is calcite.

In feeding growing chickens, a calcareous grit usually is not desirable because nearly all starting mashes and many growing mashes contain all the calcium that is required.

Sulphur.—From the standpoint of nutrition, elemental sulphur is of no value. As a matter of fact it may have harmful effects if included in the feed; it interferes with the absorption of vitamin D and with the deposition of pigment in the shanks and skin.

Mineral mixtures.—It is not possible to formulate a complete mineral mixture that is suitable for use in all diets or formula feeds. The use of so-called complete mineral mixtures is not recommended. Recent experimental findings indicate, however, that it is feasible—and often is desirable—to add small quantities of manganese sulphate, potassium iodide, ferrous sulphate, copper sulphate, and cobalt carbonate (or sulphate) to

ground limestone or calcite flour and use the resulting mineral mixture as a source of the essential trace mineral elements. If potassium iodide is not included in the mixture, salt may be used in place of the ground limestone or calcite flour. Potassium iodide is not very stable in the presence of salt. It should be noted that if salt is used as the base, instead of ground limestone or calcite flour, somewhat more than twice as much of the trace minerals should be added because salt should not be used at a level in excess of 0.5 per cent of the total feed.

The following mineral mixture is suggested for use when it is desired to include, along with a part of or all the calcium, known quantities of the trace minerals in a feed mixture:

MINERAL MIXTURE NO. 1

Ingredient	Parts, by weight
Calcite flour or ground limestone	100.0
Manganese sulphate (65%)	0.86
Potassium iodide, stabilized (90%)	0.067
Ferrous sulphate (heptahydrate)	1.02
Copper sulphate (pentahydrate)	0.102
Cobalt carbonate	0.0042
Total	102.0532

When this mineral mixture is included in a formula feed at the rate of 1 per cent (20 pounds per ton), it will add to that feed:

Calcium	0.34-0.38 per cent
Manganese	20 PPM*
Iodine	4.5 PPM
Iron	20 PPM
Copper	2.5 PPM
Cobalt	0.2 PPM

*The same quantity of manganese as would be added by the inclusion of 2⅝ ounces of feeding grade manganese sulphate in a ton of formula feed.

If it is desired to have a more concentrated pre-mix that is to be used primarily to supply the trace mineral elements, the following mineral mixture may be used:

MINERAL MIXTURE NO. 2

Ingredient	Parts, by weight
Calcite flour or ground limestone	100.0
Manganese sulphate (65%)	4.69
Potassium iodide, stabilized (90%)	0.37
Ferrous sulphate (heptahydrate)	5.56
Copper sulphate (pentahydrate)	0.552
Cobalt carbonate	0.023
Total	111.235

When this mineral mixture is included in a formula feed at the rate of 0.2 per cent (4 pounds per ton), it will add to that feed the same quantities of the trace mineral elements as the inclusion of 1 per cent (20 pounds per ton) of Mineral Mixture No. 1. It should be noted, however, that the inclusion of 0.2 per cent of Mineral Mixture No. 2 in a formula feed will add to that feed only 0.06 to 0.07 per cent of calcium.

MANAGEMENT AND FEEDING

There are numerous systems of managing and feeding chickens. Some systems yield better results under certain conditions than others, either because they tend to ensure better nutrition or because they save labor. However, it is much more important to supply the chickens with adequate quantities of all the necessary nutrients than it is to follow a given system. Any system that ensures, through design or by accident, an adequate supply of all the necessary nutrients is sure to be successful from the standpoint of nutrition. On the other hand, any system that ignores the principles of sanitation and economics may fail, no matter how well the chickens are nourished.

Housing and Management

When chickens are kept without access to the soil and sunshine, more attention must be given to their diet than when they are not so kept. This is accounted for, in part, by the fact that sunshine may serve as a source of vitamin D, and green growing grass and other plants may serve as sources of all the vitamins except vitamin D. Moreover, chickens that have access to the soil are much less likely to suffer from a deficiency of certain mineral elements, for example, manganese, than are those that do not have access to the soil.

It is a common practice to confine laying stock in laying houses during the fall, winter, and early spring, or even throughout the year. Usually the laying houses have open fronts, and that permits the chickens to have access to some sunshine; but in some cases the chickens receive no sunshine during the entire time they are in laying quarters. When the laying houses

have open fronts, the chickens may receive the equivalent of at least a part of their vitamin D requirement from sunshine. When the chickens do not have access to sunshine, they must obtain their full requirement of vitamin D from their feed. Regardless of whether or not the chickens have access to sunshine, it is a good practice to supply, in the feed, enough vitamin D to ensure that there will not be a partial deficiency of this very important vitamin.

Even when chickens have access to range, they may not get enough green feed to ensure an adequate supply of vitamin A and riboflavin, especially if their diets are deficient in these essential nutrients. Moreover, the soil often may not contain adequate quantities of certain essential mineral elements in available form. Thus, it is obvious that methods of housing and management—and in some instances the nature of the soil—may determine whether or not a given diet is adequate. For these reasons, the manufacturer of formula feeds should always include in his products adequate quantities of all the known-to-be essential nutrients.

Methods of Feeding

The various methods of feeding chickens involve the use of one or more of the following materials: (1) mash, dry or wet; (2) grain, cracked or whole; (3) pellets; (4) calcium supplement; (5) grit, calcareous or non-calcareous; and (6) water. In addition, condensed or liquid skim milk, buttermilk, or whey, and green feed may be supplied.

The all-mash method.—The all-mash method of feeding derives its name from the fact that all the feedstuffs are suitably ground and mixed together in the form of a mash. Grit may or may not be supplied; it is not necessary but it is desirable. In all-mash chick starting feeds and all-mash growing feeds it is cus-

tomary to include all the required calcium. In all-mash laying and breeding feeds all the calcium may be included or only a part (about 75 per cent) may be included and the remainder supplied in the form of a calcareous grit (calcite, oystershell, or limestone). When a suitable calcareous grit is used, no other kind of grit is necessary. If all the required calcium is included in the mash, any grit that is fed should be the non-calcareous type. Fresh, clean water should be available at all times.

The mash-grain method.—As its name implies, the mash-grain method involves the feeding of both mash and grain. When this method is used in feeding chicks, it is customary to start with an all-mash starting feed and to change to a growing mash after the chicks are about 8 weeks old (any time between the fourth and twelfth weeks). It is customary to include all the required calcium in growing mashes with which grain is to be fed. When all the required calcium is not included in such growing mashes, it is necessary to feed a calcareous grit. In laying and breeding mashes with which grain is to be fed, all the calcium may be included, but it is customary to include only 50 per cent and to supply the remainder in the form of a calcareous grit. When the chickens are given access to a calcareous grit, it is not necessary to supply any non-calcareous grit, but such grit may be supplied. Fresh clean water should be available at all times.

There are two common ways of using the mash-grain method. One way of using it is to give the birds free access to both the mash and grain. Another way is to allow the chickens to eat all the mash they want and to feed them a more or less fixed quantity of grain. The mash may be of the usual type or it may be of the so-called concentrate, or high-protein type.

Other methods. — There are numerous other methods of feeding chickens, but most of them, except

the grain-milk method, are modifications of the all-mash and mash-grain method. In using the grain-milk method, the chickens are usually given nothing except liquid milk, skim milk, or buttermilk to drink and are permitted to eat all the grain or grain mixture they want. A calcareous grit is fed in hoppers. This method is not widely used. It is not suitable for feeding caged chickens or those that are otherwise confined. In general, this method is not to be recommended; however, it may be used when plenty of good range is available and there is an abundance of liquid milk, skim milk, or buttermilk that, if not used in this manner, would have to be thrown away.

Some of the modifications of the all-mash and mash-grain methods of feeding involve the use of wet mash; others involve the use of pellets (pelleted mash); and still others involve the use of condensed milk by-products and other supplements. Wet mash, pellets, condensed milk products and other supplements are usually used as a means of increasing or of maintaining feed consumption.

All-mash versus mash-grain.—The most commonly used method of feeding chickens is the mash-grain method, but the all-mash method has many adherents because of its greater simplicity. The mash-grain method is the more flexible of the two and permits the poultryman who is familiar with the feed requirements of his chickens to feed them accordingly. It yields the best results in the hands of a skilled feeder. On the other hand, the all-mash system is usually the safest in the hands of the inexperienced poultryman.

In feeding growing chickens it is generally accepted that it is best to use an all-mash feed for the first 4 to 8 weeks. However, it has been demonstrated repeatedly that the all-mash method is suitable for the entire period of growth, and for the subsequent period of egg production as well. Nevertheless, many poultrymen

prefer to begin feeding grain (usually, cracked grain) sometime between the fourth and eighth weeks. This, of course, is not necessary and perhaps is undesirable if the all-mash method is to be used after the pullets begin laying eggs, but it is the proper thing to do if the mash-grain method is to be used.

In the feeding of laying chickens, one of the chief advantages of the all-mash method is that it permits the poultryman to have better control of the color of the yolks of the eggs that are produced. Moreover, this method of feeding tends to insure a greater uniformity of yolk color.

Feeding grain.—It is a common practice when grain is used, to feed it in the litter in order to give the chickens some exercise in obtaining this portion of their feed. Moreover, this method of feeding the grain is reputed to be of value in keeping the litter from packing. These supposed advantages of feeding grain in the litter are to be discounted heavily. Experience in feeding chickens, both in cages and in laying houses, indicates that the value of the exercise is much overrated; moreover, there are other ways of keeping the litter from packing. In any case, feeding grain in the litter is to be condemned as being insanitary and wasteful. The better practice is to feed the grain in hoppers.

Importance of an adequate supply of water.—If chickens cannot get all the water they need, they consume proportionately less feed. An adequate supply of water is necessary for maintaining a normal consumption of feed. Irregularities of growth often may be traced to fluctuations in feed consumption, which, in turn, may be traced to periods in which the chickens could not get water or, at least, get all they wanted. Likewise, partial molts in laying chickens may often be traced to periods in which the chickens were unable to get enough water for several days or were unable to get any water for one or two days.

FORMULATING DIETS

In formulating diets for any class of chickens, careful attention should be given to the selection, preparation, and mixing of the ingredients. Only feedstuffs of good quality should be used. Except in the case of oats, barley, and other feedstuffs having a high fiber content, fine grinding of the ingredients should be avoided. A granular, loose-textured mixture is to be preferred.

Choosing the Ingredients

The existing information about the composition and nutritive properties of feedstuffs permits one to choose the ingredients of a diet on the basis of their ability to serve as sources of one or more specific nutrients. For example, the cereal grains are used primarily as sources of readily digestible carbohydrates. Soybean meal and corn gluten meal are used as sources of supplementary protein. Fish meal, meat scrap, and dried skim milk are used to supply both the so-called animal protein factor and additional supplementary protein; also, they supply appreciable quantities of calcium and phosphorus. Bran and middlings are sources of several of the vitamins and vitamin-like factors and tend to improve the texture of a mixture of feedstuffs. Alfalfa meal is a good practical source of vitamin A activity, riboflavin, and a number of the other vitamins. D-activated animal sterol and the various feeding oils are used as sources of vitamin D; however, most feeding oils contain vitamin A as well as vitamin D. Salt is used as a source of sodium and chlorine; calcite flour, oystershell flour, and pulverized limestone, as sources of calcium; and bone meal, di-calcium phosphate, and defluorinated phosphate (rock), as sources of phosphorus and calcium.

Mixing the Ingredients

All the ingredients should be carefully mixed to ensure an even distribution of those that may be present in comparatively small quantities, such as salt, the feeding oils, and supplementary sources of the vitamins and trace mineral elements. The more bulky ingredients and those that are to be used in large quantities should be weighed out first, and then the other ingredients added. The ingredients that are to be used in small quantity may be mixed first with one of the other ingredients and then added. It is not a good practice, however, to mix feeding oils with mineral ingredients, because the latter tend to accelerate the destruction of the vitamin A and vitamin D in the former.

Succulent and Fresh Green Feeds Not Necessary

Most of the older systems of feeding required the use of succulent and fresh green feeds. Research has shown, however, that such feeds are not necessary so long as the diet supplies all the essential nutrients in adequate quantities. This does not mean that green feeds should not be used, but it does suggest that the nutrients supplied by them may be obtained more economically in other ways. For example, alfalfa meal of reasonably good quality may be used in place of fresh, green feed; and usually it will be found that its use is more economical and the results are just as satisfactory.

Formulas of Diets

The more important criteria of a satisfactory formula are:

(1) It must yield a diet or formula feed that is fully adequate in every way for the purpose for which it is intended;

(2) The resulting diet or formula feed must be palatable;

(3) The ingredients must be readily available at all times, so that substitutions of one ingredient for another will not have to be made; and

(4) The total cost of the diet or formula feed must be as low as it is possible to make it.

Obviously, it is extremely difficult to set up formulas that will satisfy all four of the above-listed criteria in all sections of this country. Certain ingredients are more readily available in some sections than in others; and certain ingredients often are cheaper in some sections than in others. Notwithstanding, one or more formulas of the commonly used types of formula feeds are presented.

All-mash diets.—The suitability and value of all-mash diets in the feeding of growing chickens are generally conceded. All-mash diets are suitable also for the production of table and hatching eggs of uniform quality and hatchability. Diets or formula feeds made according to the formulas that follow will be found to be satisfactory for feeding caged and confined chickens, as well as for feeding those that have access to sunshine and green range.

FORMULA 1a

ALL-MASH STARTING FEED

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground yellow corn	25.00	500
Pulverized oats	15.00	300
Wheat middlings, standard	15.00	300
Soybean meal	12.50	250
Corn gluten meal	9.75	195
Fish meal	8.50	170
Dried skim milk	2.50	50
Dehydrated alfalfa meal	7.50	150
Dried distillers' solubles	2.50	50
Mineral mixture No. 1[1]	1.30	26
Salt	.30	6
Feeding oil (1,000 A-400 D)[2]	.15	3
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.03% (0.6 pound per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	23.0
Arginine	1.15
Lysine	1.01
Methionine	.51
Cystine	.31
Tryptophane	.23
Glycine	more than 1.4
Isoleucine	1.16
Leucine	2.31
Phenylalanine	1.14
Threonine	.86
Valine	1.18
Histidine	.55
Tyrosine	.85
Fat (ether extract)	4.3
Crude fiber	6.5
Calcium	1.16
Phosphorus	.73
Total salt (NaCl)	.59
Potassium	.85
Magnesium	.23
	Parts per million
Manganese	62
Iodine	6[1]
Iron	more than 80
	I.U. per pound
Vitamin A	6,000-9,000[2]
	A.O.A.C. cu per pound
Vitamin D	270
	Milligrams per pound
Vitamin E	20
Riboflavin	1.8
Pantothenic acid	5.9
Choline	660
Niacin	21
Thiamine	2.6

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[1]5.85 PPM is supplied by Mineral Mixture No. 1; only about 0.15 to 0.20 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 1b.

ALL-MASH STARTING FEED

Ingredient	Pounds per 100 pounds	Pounds per ton
Pulverized oats	50.00	1,000
Wheat middlings, standard	10.00	200
Soybean meal	10.00	200
Fish meal	15.50	310
Dehydrated alfalfa meal	10.00	200
Dried distillers' solubles	3.00	60
Mineral mixture No. 1[1]	1.05	21
Salt	.30	6
Feeding oil (1,000 A-400 D)[2]	.15	3
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.03% (0.6 pound per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	22.6
Arginine	1.27
Lysine	1.17
Methionine	.52
Cystine	.30
Tryptophane	.25
Glycine	more than 1.2
Isoleucine	1.12
Leucine	1.83
Phenylalanine	1.06
Threonine	.85
Valine	1.14
Histidine	.55
Tyrosine	.70
Fat (ether extract)	4.8
Crude fiber	9.7
Calcium	1.49
Phosphorus	.90
Total salt (NaCl)	.67
Potassium	.88
Magnesium	.25
	Parts per million
Manganese	65
Iodine	5[1]
Iron	more than 90
	I.U. per pound
Vitamin A	6,500-9,500[2]
	A.O.A.C cu per pound
Vitamin D	270
	Milligrams per pound
Vitamin E	24
Riboflavin	1.9
Pantothenic acid	6.2
Choline	735
Niacin	19.7
Thiamine	3

[1]4.72 PPM is supplied by Mineral Mixture No. 1; only about 0.25 to 0.30 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 1c.

ALL-MASH STARTING FEED

Ingredient	Pounds per 100 pounds	Pounds per ton
Any grain	36.50	730
Wheat middlings, standard	15.00	300
Soybean meal	15.00	300
Corn gluten meal	9.45	189
Fish meal	6.50	130
Meat scrap (55%)	2.50	50
Dried skim milk	2.50	50
Dehydrated alfalfa meal	10.00	200
Dried distillers' solubles	1.25	25
Mineral mixture No. 1[1]	1.00	20
Salt	.27	5.4
D-activated animal sterol	.03	.6
Total	100.00	2,000.0

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

Calculated Composition

Nutrient		Per cent
Protein (N x 6.25)		23.7
Arginine		1.19
Lysine		1.05
Methionine		.51
Cystine		.32
Tryptophane		.24
Glycine	more than	1.5
Isoleucine		1.18
Leucine		2.16
Phenylalanine		1.17
Threonine		.89
Valine		1.19
Histidine		.54
Tyrosine		.75
Fat (ether extract)		3.3
Crude fiber	as much as	9.2
Calcium		1.17
Phosphorus		.75
Total salt (NaCl)		.69
Potassium		.87
Magnesium		.22
		Parts per million
Manganese		51
Iodine		4.7[1]
Iron	more than	65
		I.U. per pound
Vitamin A		7,000-10,000[2]
		A.O.A.C. cu per pound
Vitamin D		270
		Milligrams per pound
Vitamin E		20
Riboflavin		1.9
Pantothenic acid		6
Choline		625
Niacin		20.8
Thiamine		2.4

[1]4.5 PPM is supplied by Mineral mixture No. 1; only about 0.20 to 0.25 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 2.

HIGH-PROTEIN (ALL-MASH) STARTING FEED

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground yellow corn	13.00	260
Wheat middlings, standard	15.00	300
Soybean meal	20.00	400
Corn gluten meal	20.00	400
Fish meal	10.00	200
Dried skim milk	5.00	100
Dehydrated alfalfa meal	10.00	200
Dried distillers' solubles	5.00	100
Mineral mixture No. 1[1]	1.50	30
Salt	.25	5
Feeding oil (1,000 A-400 D)[2]	.25	5
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.05% (1 pound per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	30
Arginine	1.46
Lysine	1.34
Methionine	.67
Cystine	.41
Tryptophane	.30
Glycine	more than 2.1
Isoleucine	1.56
Leucine	3.26
Phenylalanine	1.55
Threonine	1.16
Valine	1.56
Histidine	.70
Tyrosine	1.15
Fat (ether extract)	4.1
Crude fiber	6.2
Calcium	1.4
Phosphorus	.85
Total salt (NaCl)	.60
Potassium	1.0
Magnesium	.25
	Parts per million
Manganese	66
Iodine	6.9[1]
Iron	more than 87
	I.U. per pound
Vitamin A	8,000-12,000[2]
	A.O.A.C. cu per pound
Vitamin D	450
	Milligrams per pound
Vitamin E	19
Riboflavin	2.5
Panothenic acid	7
Choline	850
Niacin	24.8
Thiamine	2.3

[1]6.75 PPM is supplied by Mineral mixture No. 1; only about 0.20 to 0.25 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 3.

ALL-MASH GROWING FEED.

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground oats	62.00	1,240
Wheat bran	10.00	200
Soybean meal	3.75	75
Fish meal	6.00	120
Dried skim milk	5.00	100
Dehydrated alfalfa meal	10.00	200
Dried distillers' solubles	1.25	25
Mineral mixture No. 1[1]	1.00	20
Steamed bone meal	.55	11
Salt	.35	7
Feeding oil (1,000 A-400 D)[2]	.10	2
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% of $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.02% (0.4 pound per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	17.2
Arginine	.90
Lysine	.82
Methionine	.38
Cystine	.25
Tryptophane	.20
Glycine	more than .6
Isoleucine	.83
Leucine	1.22
Phenylalanine	.78
Threonine	.59
Valine	.89
Histidine	.44
Tyrosine	.49
Fat (ether extract)	4.3
Crude fiber	10.6
Calcium	1.24
Phosphorus	.72
Total salt (NaCl)	.67
Potassium	.81
Magnesium	.24
	Parts per million
Manganese	60
Iodine	4.6[1]
Iron	more than 85
	I.U. per pound
Vitamin A	6,500-9,500[2]
	A.O.A.C. cu per pound
Vitamin D	180
	Milligrams per pound
Vitamin E	26
Riboflavin	1.9
Pantothenic acid	7
Choline	545
Niacin	23.8
Thiamine	3

[1]4.5 PPM is supplied by Mineral mixture No. 1; only about 0.10 to 0.15 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 4.

ALL-MASH FEED FOR LAYING AND BREEDING CHICKENS.

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground oats	59.00	1,180
Wheat bran	10.00	200
Soybean meal	3.75	75
Fish meal	6.00	120
Dried skim milk	5.00	100
Dehydrated alfalfa meal	10.00	200
Mineral mixture No. 1[1]	1.00	20
Calcite flour (or ground limestone)	2.50	50
Steamed bone meal	2.10	42
Salt	.375	7.5
Feeding oil (1,000 A-400 D)[2]	.275	5.5
Total	100.000	2,000.0

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.055% (1.1 pounds per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	16.7
Arginine	.89
Lysine	.81
Methionine	.37
Cystine	.24
Tryptophane	.19
Glycine	more than .5
Isoleucine	.80
Leucine	1.18
Phenylalanine	.75
Threonine	.57
Valine	.86
Histidine	.42
Tyrosine	.48
Fat (ether extract)	4.1
Crude fiber	10.3
Calcium	2.46
Phosphorus	.90
Total salt (NaCl)	.69
Potassium	.78
Magnesium	.29
	Parts per million
Manganese	63
Iodine	4.6[1]
Iron	more than 127
	I.U. per pound
Vitamin A	7,000-10,000[2]
	A.O.A.C. cu per pound
Vitamin D	499
	Milligrams per pound
Vitamin E	26
Riboflavin	1.8
Pantothenic acid	6.7
Choline	500
Niacin	22.8
Thiamine	2.8

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[1]4.5 PPM is supplied by Mineral mixture No. 1; only about 0.10 to 0.15 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 5a.

FINISHING FEED FOR BROILERS

Ingredient	Pounds, per 100 pounds of air-dry feed	Pounds, per ton of air-dry feed
Ground yellow corn	34.50	690
Pulverized oats	25.00	500
Wheat middlings, standard	12.50	250
Soybean meal	5.00	100
Corn gluten meal	5.00	100
Meat scrap (55%)	10.00	200
Dehydrated alfalfa meal	5.00	100
Corn oil[1]	2.23	44.6
Mineral mixture No. 1[2]	.75	15.0
D-activated animal sterol	.02	0.4
Water	[3]	[3]
Total air-dry feed	100.00	2,000.0

[1]Any digestible oil or fat may be used in place of the corn oil; for example, red palm oil, rapeseed oil, peanut oil, beef fat, or mutton tallow.

[2]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[3]Enough water to give the desired consistency should be added before feeding.

Calculated Composition

Nutrient	Per cent
Protein	18.3
Fat (ether extract)	6.8
Crude fiber	6.4
Calcium	1.2
Phosphorus	.76
Total salt (NaCl)	.45
Manganese	.0045*

*Or 45 PPM.

	I.U. per pound
Vitamin A	3,500-5,500[1]

	A.O.A.C. cu per pound
Vitamin D	180

	Milligrams per pound
Vitamin E	18
Riboflavin	1.2
Pantothenic acid	4.8
Choline	475

[1]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 5b.

FINISHING FEED FOR BROILERS.

Ingredient	Pounds, per 100 pounds of air dry feed	Pounds per ton of air-dry feed
Ground corn	35.00	700
Finely ground barley	25.00	500
Wheat middlings, standard	15.00	300
Soybean meal	2.50	50
Corn gluten meal	2.50	50
Meat scrap (55%)	12.50	250
Dehydrated alfalfa meal	5.00	100
Corn oil[1]	1.78	35.6
Mineral mixture No. 1[2]	.78	14.0
D-activated animal sterol	.02	.4
Water	[3]	[3]
Total air-dry feed	100.00	2,000.0

[1]Any digestible oil or fat may be used in place of the corn oil; for example, red palm oil, rapeseed oil, peanut oil, beef fat, or mutton tallow.

[2]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[3]Enough water to give the desired consistency should be added before feeding.

Calculated Composition

Nutrient	Per cent
Protein	18.1
Fat (ether extra)	6.0
Crude fiber	5.2
Calcium	1.37
Phosphorus	.85
Total salt (NaCl)	.54
Manganese	.0042*

*Or 42 PPM.

	I.U. per pound
Vitamin A	3,200-5,200[1]

	A.O.A.C. cu per pound
Vitamin D	180

	Milligrams per pound
Vitamin E	18
Riboflavin	1.2
Pantothenic acid	4.4
Choline	485

[1]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 6a.

FINISHING FEEDS FOR ROASTERS AND FOWLS.

Ingredient	Pounds, per 100 pounds of air dry feed	Pounds per ton of air-dry feed
Ground corn	35.00	700
Pulverized oats	34.00	680
Wheat middlings, standard	15.00	300
Soybean meal	2.50	50
Meat scrap (55%)	5.00	100
Dehydrated alfalfa meal	2.00	40
Corn oil[1]	5.00	100
Mineral mixture No. 1[2]	1.29	25.8
Salt	.20	4.0
D-activated animal sterol	.01	.2
Water	[3]	[3]
Total air-dry feed	100.00	2,000.0

[1]Any digestible oil or fat may be used in place of the corn oil; for example, red palm oil, rapeseed oil, peanut oil, beef fat, or mutton tallow.

[2]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[3]Enough water to give the desired consistency should be added before feeding.

Calculated Composition

Nutrient	Per cent
Protein	13.4
Fat (ether extract)	9.45
Crude fiber	6.4
Calcium	.94
Phosphorus	.58
Total salt (NaCl)	.47
Manganese	.0059*

*Or 59 PPM.

	I.U. per pound
Vitmain A	1,800-2,700[1]

	A.O.A.C. cu per pound
Vitamin D	90

	Milligrams per pound
Vitamin E	16
Riboflavin	.85
Pantothenic acid	4.3
Choline	385

[1]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 6b.

FINISHING FEED FOR ROASTERS AND FOWLS

Ingredient	Pounds, per 100 pounds of air dry feed	Pounds per ton of air-dry feed
Ground corn	34.00	680
Finely ground barley	30.00	600
Wheat middlings, standard	20.00	400
Meat scrap (55%)	7.50	150
Dehydrated alfalfa meal	2.00	40
Corn oil[1]	5.00	100
Mineral mixture No. 1[2]	1.29	25.8
Salt	.20	4.0
D-activated animal sterol	.01	.2
Water	[3]	[3]
Total air-dry feed	100.00	2,000.0

[1]Any digestible oil or fat may be used in place of the corn oil, for example, red palm oil, rapeseed oil, peanut oil, beef fat, or mutton tallow.

[2]Formula given on page 172. Or use a mixture of calcite flour and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[3]Enough water to give the desired consistency should be added before feeding.

Calculated Composition

Nutrient	Per cent
Protein	14.0
Fat (ether extract)	8.75
Crude fiber	4.7
Calcium	1.13
Phosphorus	.69
Total salt (NaCl)	.56
Manganese	.0058*

*Or 58 PPM.

	I.U. per pound
Vitamin A	1,800-2,700[1]

	A.O.A.C. cu per pound
Vitamin D	90

	Milligrams per pound
Vitamin E	15
Riboflavin	.9
Pantothenic acid	3.9
Choline	410

[1]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 7.

ALL-MASH FEED FOR SEGREGATED BREEDING MALES.

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground yellow corn	40.00	800
Ground oats	30.00	600
Wheat middlings, standard	13.50	270
Fish meal	5.00	100
Dried whey	5.00	100
Dehydrated alfalfa meal	5.00	100
Mineral mixture No. 1[1]	1.15	23
Salt	.30	6
Feeding oil (1,000 A-400 D)	.05	1
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

Calculated Composition

Nutrient	Per cent
Protein	13.4
Fat (ether extract)	3.6
Crude fiber	5.3
Calcium	.85
Phosphorus	.55
Total salt (NaCl)	.54
Manganese	.0055*

*Or 55 PPM.

	I.U. per pound
Vitamin A	4,200-5,600[1]
	A.O.A.C. cu per pound
Vitamin D	90
	Milligrams per pound
Vitamin E	19
Riboflavin	1.6
Pantothenic acid	5.5
Choline	400

[1]Depends chiefly on the carotene content of the alfalfa meal.

Mash-grain diets.—In using the mash-grain method of feeding, it should be remembered that the several grains are poor sources of protein, vitamin A activity (excepting yellow corn), riboflavin, and calcium. Moreover, the grains contain no appreciable quantity of vitamin D. Accordingly, in formulating mashes with which grain is to be fed, it is necessary to give special attention to the quantities of nutrients they are to

supply, especially to the protein, vitamin A activity, vitamin D, calcium, and manganese.

Inasmuch as a feed manufacturer does not know what grain or mixture of grains will be fed with his mashes, he should formulate his mashes so that they will supply adequate quantities of all the nutrients regardless of the grain that is fed. As an aid in doing that, the concept of "any grain" will be found useful. "Any grain" is defined as a hypothetical grain that contains not more of any nutrient than any actual grain (excluding rye). Thus, "any grain" will supply as much—but no more—protein, calcium, phosphorus, and manganese as corn; as much—but no more—vitamin A as wheat; and so on. It will, however, supply as much crude fiber as oats. The composition of "any grain" is given in the following tabulation.

COMPOSITION OF "ANY GRAIN"
(Minimum values)

Nutrient	Per cent
Protein	9.0
Arginine	.36
Lycine	.21
Methionine	.21
Cystine	.12
Tryptophane	.06
Glycine	?
Isoleucine	.41
Leucine	.61
Phenylalanine	.44
Threonine	.25
Valine	.44
Histidine	.18
Tyrosine	.12
Fat (ether extract)	1.7
Crude fiber	11.0[1]
Calcium	.01
Phosphorus	.27
Salt equivalent	.08
Manganese	.0005*

*Or 5 PPM.

	I.U. per pound
Vitamin A	125

	Milligrams per pound
Vitamin E	12
Riboflavin	.5
Pantothenic acid	2.7
Choline	200

[1]Maximum rather than minimum value.

FORMULA 8.

STARTING-AND-GROWING MASH.

Ingredient	Pounds per 100 pounds	Pounds per ton
Finely ground oats	31.50	630
Wheat bran	20.00	400
Soybean meal	7.50	150
Fish meal	12.00	240
Dried skim milk	10.00	200
Dehydrated alfalfa meal	12.50	250
Dried distillers' solubles	2.50	50
Mineral mixture No. 1[1]	2.00	40
Steamed bone meal	1.30	26
Salt	.50	10
Feeding oil (1,000 A-400 D)[2]	.20	4
Total	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

[2]If a good grade of alfalfa meal is used, the feeding oil may be replaced by 0.04% (0.8 pound per ton) of D-activated animal sterol that contains 900,000 A.O.A.C. chick units of vitamin D per pound.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	22.9
Arginine	1.23
Lysine	1.24
Methionine	.52
Cystine	.30
Tryptophane	.27
Glycine	more than .9
Isoleucine	1.15
Leucine	1.70
Phenylalanine	1.04
Threonine	.84
Valine	1.22
Histidine	.58
Tyrosine	.63
Fat (ether extract)	4.3
Crude fiber	9.2
Calcium	2.15
Phosphorus	1.14
Total salt (NaCl)	.99
Potassium	1.06
Magnesium	.32
	Parts per million
Manganese	87
Iodine	9.2[1]
Iron	more than 100
	I.U. per pound
Vitamin A	8,000-12,000[2]
	A.O.A.C. cu per pound
Vitamin D	360
	Milligrams per pound
Vitamin E	23
Riboflavin	2.8
Pantothenic acid	8.4
Choline	665
Niacin	40
Thiamine	2.6

[1]9.0 PPM is supplied by Mineral mixture No. 1; only about 0.2 to 0.25 PPM is supplied by the other ingredients.

[2]Depends chiefly on the carotene content of the alfalfa meal.

FORMULA 9.

LAYING-AND-BREEDING MASH

Ingredient	Pounds per 100 pounds	Pounds per ton
Ground oats	33.50	670
Wheat bran	20.00	400
Soybean meal	3.75	75
Corn gluten meal	3.75	75
Fish meal	12.00	240
Dried skim milk	10.00	200
Dehydrated alfalfa meal	10.00	200
Dried distillers' solubles	2.65	53
Mineral mixture No. 1[1]	2.00	40
Steamed bone meal	1.30	26
Salt	.50	10
Feeding oil (1,000 A-400 D)	.55	11
	100.00	2,000

[1]Formula given on page 172. Or use a mixture of calcite flour (or ground limestone) and manganese sulphate (65% $MnSO_4$) in the ratio of 1,000 to 9.

Calculated Composition

Nutrient	Per cent
Protein (N x 6.25)	22.7
Arginine	1.18
Lysine	1.16
Methionine	.53
Cystine	.29
Tryptophane	.26
Glycine	more than .75
Isoleucine	1.15
Leucine	1.87
Phenylalanine	1.04
Threonine	.82
Valine	1.21
Histidine	.57
Tyrosine	.66
Fat (ether extract)	4.6
Crude fiber	8.6
Calcium	2.11[1]
Phosphorus	1.12
Total salt (NaCl)	.98
Potassium	.94
Magnesium	.31
	Parts per million
Manganese	86
Iodine	9.2[2]
Iron	more than 100
	I.U. per pound
Vitamin A	9,000-12,000[3]
	A.O.A.C. cu per pound
Vitamin D	990
	Milligrams per pound
Vitamin E	20
Riboflavin	2.6
Pantothenic acid	8.1
Choline	645
Niacin	40
Thiamine	2.5

[1]More calcium than this is required for maximum egg production. It may be supplied by giving the chickens free access to a calcium supplement or by adding approximately 115 pounds of calcite flour (or ground limestone) to each ton of this mash.

[2]9.0 PPM is supplied by Mineral mixture No. 1; only about 0.2 to 0.25 PPM is supplied by the other ingredients.

[3]Depends chiefly on the carotene content of the alfalfa meal.

USEFUL INFORMATION FOR FORMULATING DIETS

Information of value in formulating diets for chickens is given in the pages that follow. This information includes (1) the nutrient allowances for chickens recommended by the National Research Council (Revised, November 1, 1946), (2) summary of nutrient allowances recommended by the writer, (3) practical levels of nutrients in different types of formula feeds, and (4) tables that give (a) the average composition, (b) the mineral content (calcium, phosphorus, manganese, magnesium, potassium, sodium, minimum salt equivalent, iron, iodine, and copper), (c) the vitamin content (vitamin A, vitamin D, vitamin E, riboflavin, pantothenic acid, choline, niacin, and thiamine), (d) the amino acid content (arginine, lysine, methionine, cystine, tryptophane, glycine, isoleucine, leucine, phenylalanine, threonine, valine, histidine, and tyrosine), and (3) the digestibility and total digestible nutrients (TDN) of some feedstuffs used in the feeding of poultry.

The National Research Council's Recommended Nutrient Allowances for Chickens
(Revised November 1, 1946)

Nutrient	Chicks, 0–8 wks.	Chicks, 8–18 wks.	Laying hens	Breeding hens
Total protein, per cent	20	16	15	15
Calcium, per cent	1	1	2 25[1]	2 25[1]
Phosphorus, per cent[2]	6	.6	75	.75
Added salt (NaCl), per cent	.5	5	.5	.5
Manganese, mg per pound	25	?	?	15
(Manganese, parts per million	55	?	?	33)
Iodine, mg per pound	.5	5	.5	.5
(Iodine, parts per million[3].	1 1	1 1	1 1	1.1)
Vitamin A activity, I. U. per lb.[4]	2,000	2,000	3,300	3,300
Vitamin D, A.O.A.C. cu per lb.	180	180	450	450
Riboflavin, mg per lb.	1 6	9	9	1.3
Pantothenic acid, mg per lb.	5	?	2 5	5
Choline, mg per lb.	700	?	?	?
Niacin, mg per lb.	8	?	?	?
Thiamine, mg per lb.	.9	?	?	?
Pyridoxine, mg per lb.	1.6	?	1 6	1 6
Biotin, mg per lb.	.045	?	?	.07

[1]This amount of calcium need not be incorporated in the mixed feed inasmuch as calcium supplements fed free choice are considered as part of the ration.

[2]Inorganic phosphorus should constitute 0.2 per cent of the total feed.

[3]This allowance is larger than that specified in National Research Council Reprint and Circular Series No. 111, May, 1942, "Iodine—Its Necessity and Stabilization," because of changes in the feed supply which increase the need for iodine.

[4]May be fish oil vitamin A or provitamin A from vegetable sources.

The National Research Council's Tentative Requirements of Chicks (0-8 Weeks) for Certain Amino Acids, Vitamins and Minerals)

(Revised November 1, 1946)

Amino acids:[1]	
Glycine, per cent	1.0
Arginine, per cent	1.0
Methionine, per cent	0.9
or	
Methionine, per cent	0.5
Cystine, per cent	0.4
Lysine, per cent	0.9
Tryptophane, per cent	0.25
Vitamins:	
Vitamin K, mg per lb.	0.18
Minerals:	
Potassium, grams per lb.	0.8
(Potassium, per cent	0.176)
Magnesium, mg per lb.	180.0
(Magnesium, per cent	0.04)
Iron, mg per lb.	9.0
(Iron, parts per million	20.0)
Copper, mg per lb.	0.9)
(Copper, parts per million	2.0)

[1]At the Annual Nutrition Conference for Feed Manufacturers, Cornell University, Ithaca, New York, December 4-6, 1945, Dr. H. J. Almquist listed the amino acid requirements as follows: Glycine, 0.8 per cent; arginine, 0.9 per cent; methionine, 0.5 per cent; cystine, 0.3 per cent; lysine, 0.9 per cent, and tryptophane, 0.2 per cent.

Summary of Nutrient Allowances for Growing Chickens (Starting Feed)

Nutrient	Quantity	Practical range
Protein (N x 6.25)	21.0 %[1]	20.0– 23.0 %, or more
Arginine	1.0 %	
Lysine	1.0 %	
Methionine	.5 %	
Cystine	.3 %	
Tryptophane	.25 %	
Glycine	.8 %	
Isoleucine	6 %	
Leucine	1.4 %	
Phenylalanine	.95 %	
Threonine	.7 %	
Valine	.8 %	
Histidine	.35 %	
Tyrosine	.75 % (replaceable by phenylalanine)	
Calcium (total)	1.2 %	1 0 – 1 5 %
Phosphorus (total)	.8 %	0.6 – 0 9 %
Inorganic phosphorus	.2 %	0.2 – 0.3 %, or more
Salt (total)	.5 %	0.4 – 0.7 %
Added salt	.3 %	0.25– 0.4 %
Potassium	.25 %	0.17– 1 3 %
Magnesium	.04 %	0 04– 0 5 %
Manganese (total)	50 PPM	50 – 100 PPM, or more
Added manganese	20 PPM	10 – 30 PPM, or more
Iodine (total)	5 PPM	2 – 5 PPM, or more
Added iodine	4.5 PPM	2 – 4.5 PPM, or more
Iron	30 PPM	30 – 100 PPM, or more
Copper	3 PPM	2 – 5 PPM, or more
Cobalt	? PPM	0.05– 0.2 PPM, or more
Vitamin A	2,000 I.U. per lb.	2,000 –12,000 I.U. per lb.
Vitamin D	270 A.O.A.C. cu per lb.	180 – 270 A.O.A.C. cu per lb.
Vitamin E	9 mg per lb.	9 – 25 mg per lb., or more
Vitamin K	.18 mg per lb.	
Riboflavin	1.7 mg per lb.[2]	1.6 – 1.8 mg per lb., or more
Pantothenic acid	5.0 mg per lb.	5 – 7 mg per lb., or more
Choline	650 mg per lb.	600 – 700 mg per lb., or more
Niacin	7.0 mg per lb.[3]	7.0 – 50.0 mg per lb., or more
Thiamine	.7 mg per lb.	0.7 – 3.0 mg per lb., or more
Pyridoxine	1.5 mg per lb.	
Biotin	.045 mg per lb.	
Folic acid	.25 mg per lb.	

[1]After the eight week the allowance of protein may be reduced to 16 per cent (practical range: 15-17 per cent). Also, the allowance of the several amino acids may be reduced to 70 per cent of these allowances.

[2]After the eighth week the allowance of riboflavin may be reduced to 1.2 mg per pound (practical range: 1.0–1.4 mg per pound, or more).

[3]See statement at the top of page 97.

Summary of Nutrient Allowances for Laying and Breeding Chickens

Nutrient	Quantity	Practical range
Protein (N x 6.25)	15.0 %	15.0 – 17.0 %
Arginine	.50 %	
Lysine	.45 %	
Methionine	.37 %	
Cystine	.19 %	
Tryptophane	.12 %	
Glycine	.18 %	
Isoleucine	.61 %	
Leucine	.70 %	
Phenylalanine	.46 %	
Threonine	.35 %	
Valine	.56 %	
Histidine	.16 %	
Tyrosine	.36 % (replaceable by phenylalanine)	
Calcium (total)	2.3 %	2.0 – 2.8 % (see page 101 and table 7)
Phosphorus (total)	.8 %	0.7 – 1.3 % (see table 7)
Salt (total)	.5 %	0.4 – 0.7 %
Added salt	.3 %	0.25– 0.4 %
Manganese (total)	50 PPM	35 – 100 PPM, or more
Added manganese	20 PPM	10 – 30 PPM, or more
Iodine (total)	.5 PPM	.2 – .5 PPM
Added iodine	.45 PPM	.2 – .45 PPM
Vitamin A		
Laying chickens	3,300 I.U. per lb.	3,300 –12,000 I.U. per lb.
Breeding chickens	4,500 I.U. per lb.	3,300 –12,000 I.U. per lb.
Vitamin D	500 A.O.A.C. cu per lb.	450 – 500 A.O.A.C. cu per lb.
Riboflavin		
Laying chickens	1.1 mg per lb.	1.0 – 1.2 mg per lb., or more
Breeding chickens	1.5 mg per lb.	1.4 – 1.6 mg per lb., or more
Pantothenic acid		
Laying chickens	4.5 mg per lb.	4.0 – 4.5 mg per lb., or more
Breeding chickens	5.5 mg per lb.	5.0 – 5.5 mg per lb., or more
Choline	500 mg per lb.	450 – 500 mg per lb., or more
Pyridoxine	1.5 mg per lb.	1.0 – 1.5 mg per lb., or more
Biotin	.07 mg per lb.	

Summary of Nutrient Allowances for Other Classes of Chickens

Broilers Being Finished (Fattened) for Market

Nutrient	Quantity
Protein (N x 6.25)	16 – 20 %
Fat (ether extract)	1 – 4 % of fat may be **added**
Vitamin D	180 A.O.A.C. cu per lb.
Other vitamins	Approximately same as for growing chickens
Mineral elements	Approximately same as for growing chickens

Fryers, Roasters, Capons, and Fowls Being Finished (Fattened) for Market

Nutrient	Quantity		
Protein (N x 6.25)	12	– 14	%
Fat (ether extract)	6	– 10	%
Added fat	2.5	– 6	%
Calcium	about 1.0		%
Phosphorus	about 5		%
Vitamin A	1,800		I.U. per lb., or more
Vitamin D	90		A.O.A.C. cu per lb.

Segregated Breeding Males

Nutrient	Quantity		
Protein	13	– 14	%
Calcium	0.6	– 0.9	%
Phosphorus	0.4	– 0.6	%
Vitamin A	2,000		I.U. per lb., or more
Vitamin D	75		A.O.A.C. cu per lb., or more
Riboflavin	1		mg per lb., or more

Practical Levels of Nutrients In Different Types of Formula Feeds

All-mash starting feeds.—Same as given in Summary of Nutrient Allowances for Growing Chickens (Starting Feed).

High-protein (all-mash) starting feeds.—Most high-protein starters contain 28-32 per cent of protein and somewhat more of the mineral elements and vitamins than the usual type of all-mash starting feeds. It is not enough, however, to merely increase the protein from the usual level to 28-32 per cent; it is essential that the required amino acids be increased about 30 per cent. The following-listed levels of the several nutrients are suggested:

Nutrient	Quantity			
Protein (N x 6.25)	28	-	32	%
Arginine	1.3			%
Lysine	1.3			%
Methionine	.65			%
Cystine	.40			%
Tryptophane	.33			%
Glycine	1.1			%
Isoleucine	.8			%
Leucine	1.8			%
Phenylalanine	1.2			%
Threonine	.95			%
Valine	1.05			%
Histidine	.90			%
Tyrosine	1.0			% (replaceable by phenylalanine)
Calcium	1.2	-	1.6	%, or somewhat more
Phosphorus	0.8	-	1.0	%, or somewhat more
Salt (total)	0.5	-	0.7	%
Manganese (total)	65			PPM, or more
Iodine (total)	2	-	5	PPM
Vitamin A	2,500			I.U. per lb., or more
Vitamin D	270	-	450	A.O.A.C. cu per lb.
Vitamin E	12			mg per lb., or more
Riboflavin	2.2			mg per lb., or more
Pantothenic acid	6.5			mg per lb., or more
Choline	800			mg per lb., or more
Niacin	9			mg per lb., or more

All-mash growing feeds.—A desirable level of protein is 16 per cent, but this class of feeds may contain 15 to 17 per cent, or more. See Summary of Nutrient Allowances for Growing Chickens (Starting Feed), especially the second sentence in footnote 1. In general, all-mash growing feeds need not contain more than 180 A.O.A.C. chick units of vitamin D per pound, but a larger quantity may be included if desired.

All-mash feeds for laying and breeding chickens.—Same as given in Summary of Nutrient Allowances for Laying and Breeding Chickens. It is to be noted that all-mash feeds for laying chickens need not contain as much vitamin A, riboflavin, and pantothenic acid as all-mash feeds for breeding chickens.

Other all-mash feeds.—See Summary of Nutrient Allowances for Other Classes of Chickens.

Mashes with which grain is to be fed.—Mashes intended to be fed with grain should be so formulated that they may be fed with *any* grain. (See par. 1, page 199). The following-listed practical levels of nu-

trients in starting-and-growing mashes and laying-and breeding mashes permit such mashes to be fed with any grain.

Starting-and-growing mashes.—On the assumption that an all-mash growing feed should contain at least 70 per cent as much of each required amino acid as an all-mash starting feed, it follows that, when a starting-and-growing mash is fed with an equal quantity of any grain, the combination of mash and grain should also supply at least 70 per cent as much of each amino acid as an all-mash starter. Also, a starting-and-growing mash should supply at least as much of each amino acid as an all-mash starting feed. Moreover, a mixture of equal parts of a starting-and-growing mash and of grain should supply approximately as much of the other essential nutrients as an all-mash growing feed. Accordingly, suitable practical levels of nutrients in *starting-and-growing mashes* are as follows:

Nutrient	Quantity		
Protein (N x 6.25)	21 -	23	%
Arginine	1.04		%
Lysine	1.19		%
Methionine	.50		%
Cystine	.30		%
Tryptophane	.29		%
Glycine	.80		%
Isoleucine	.60		%
Leucine	1.40		%
Phenylalanine	.95		%
Threonine	.73		%
Valine	.80		%
Histidine	.35		%
Tyrosine	.93		% (replaceable by phenylalanine)
Calcium	2.0 -	2.8	%
Phosphorus	1.0 -	1.5	%
Salt (total)	0.8 -	1.2	%
Added salt	0.4 -	0.7	%
Manganese (total)	85		PPM, or more
Added manganese	40 -	60	PPM
Iodine (total)	4 -	10	PPM
Added iodine	4 -	9	PPM
Vitamin A	3,300 -	4,000	I. U. per lb., or more
Vitamin D	360		A.O.A.C. cu per lb.
Vitamin E	9		mg per lb., or more
Riboflavin	1.6 -	1.8	mg per lb., or more
Pantothenic acid	5.5		mg per lb., or more
Choline	600		mg per lb., or more

Laying-and-breeding mashes.—In laying-and-breeding mashes suitable practical levels of nutrients are as follows:

Nutrient	Quantity		
Protein (N x 6.25)	20	- 23	%
Arginine	0.64		%
Lysine	.69		%
Methionine	.53		%
Cystine	.26		%
Tryptophane	.18		%
Glycine	.36		% (?)
Isoleucine	.81		%
Leucine	.79		%
Phenylalanine	.48		%
Threonine	.45		%
Valine	.68		%
Histidine	.14		%
Tyrosine	.60		% (replaceable by phenylalanine)
Calcium	3.7	- 4.6[1]	%
	1.9	- 2.3[2]	%
Phosphorus	0.8	- 1.5	%
Salt (total)	0.8	- 1.2	%
Added salt	0.4	- 0.7	%
Manganese (total)	75		PPM, or more
Added manganese	30	- 50	PPM
Iodine (total)	4	- 10	PPM
Added iodine	4	- 9	PPM
Vitamin A			
Laying stock	6,600		I.U. per lb., or more
Breeding stock	6,600	-9,000	I.U. per lb., or more
Vitamin D	900	-1,000	A.O.A.C. cu per lb., or more
Riboflavin			
Laying stock	1.5	- 1.9	mg per lb., or more
Breeding stock	2.3	- 2.7	mg per lb., or more
Pantothenic acid			
Laying stock	4.5	- 5.5	mg per lb., or more
Breeding stock	6.0	- 7.0	mg per lb., or more
Choline	600	- 700	mg per lb., or more

[1]If the mashes are to supply all the needed calcium.

[2]If a calcium supplement is to be fed.

Table 8.—The average composition of some feedstuffs used in the feeding of poultry.

Feedstuff	Moisture	Ash	Crude protein	Carbohydrates		Fat, or ether extract
				Crude fiber	Nitrogen-free extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Grains and seeds, and their byproducts						
Acorns of the willow oak	11.3	1.6	4.4	16.5	46.8	19.4
Babassu meal	9.0	5.0	23.0	12.0	44.0	7.0
Barley	11.0	2.9	11.0	6.0	67.0	2.1
Barley (Pacific Coast States)	10.1	2.6	8.7	5.7	71.0	1.9
Beans, mung	11.3	3.0	21.7	4.0	59.4	.6
Beans, navy	13.4	3.6	22.7	5.8	53.0	1.5
Beans, pinto	9.1	4.5	22.7	4.5	58.0	1.2
Bread	33.8	1.5	7.9	.7	55.4	.7
Bread, kiln dried	10.5	2.2	12.5	.5	72.7	1.6
Brewers' grain, dried	7.5	3.9	26.0	16.0	39.9	6.7
Broom corn	11.6	3.1	10.5	8.3	63.0	3.5
Buckwheat	11.9	1.8	10.1	10.4	63.5	2.3
Buckwheat middlings	11.4	4.7	28.6	6.0	42.2	7.1
Coconut meal, old process	9.3	6.1	20.5	11.1	44.7	8.3
Coconut meal, solvent extracted	9.5	6.6	22.1	11.9	47.4	2.5
Corn or ground corn	12.0	1.3	9.0	2.0	71.5	4.2
Corn, Argentine	11.0	1.7	11.0	1.8	68.8	5.7
Corn-and-cob meal	11.5	2.1	8.2	11.0	64.2	3.0
Corn bran	10.0	2.4	8.6	10.3	63.7	5.0
Corn feed meal	11.0	1.8	9.0	3.0	71.2	4.0
Corn germ meal	9.0	3.0	20.0	9.0	51.0	8.0

Corn gluten feed	9.5	6.0	25.0	7.5	49.0	3.0
Corn gluten meal	9.0	2.0	41.0	3.0	43.0	2.0
Corn oil-cake meal	9.0	2.2	22.0	10.5	49.0	7.3
Cottonseed meal (43%)	7.3	5.9	43.0	12.0	25.8	6.0
Cottonseed meal (41%)	7.5	6.0	41.0	13.0	27.0	5.5
Cowpeas	11.1	3.5	23.5	4.1	56.3	1.5
Distillers' dark grain (corn), dried	11.0	6.0	28.0	7.0	39.0	9.0
Distillers' dark grains, dried	11.0	6.0	28.0	7.0	40.0	8.0
Durra	10.0	2.0	10.2	1.7	72.6	3.5
Emmer	10.5	3.0	11.5	10.0	63.0	2.0
Feterita	10.2	1.6	13.2	1.8	70.2	3.0
Field peas	9.3	3.3	23.2	5.9	57.0	1.2
Flaxseed	11.5	4.5	22.0	7.0	23.0	32.0
Garden peas, dried	11.8	3.0	25.6	4.4	53.6	1.6
Hegari	10.5	2.0	9.5	2.5	73.0	2.5
Hempseed	7.6	5.9	22.9	18.6	18.4	26.6
Hempseed meal	7.3	7.8	31.7	23.9	25.3	4.0
Hominy	11.8	.7	7.4	.6	77.6	1.9
Hominy feed	8.5	3.0	11.0	6.0	65.0	6.5
Kafir	12.0	1.6	11.0	2.4	70.0	3.0
Linseed meal	9.7	5.8	34.0	8.5	36.0	6.0
Malt sprouts, dried	7.9	5.9	26.0	13.0	45.7	1.5
Millet (proso)	9.6	3.4	11.6	8.7	63.1	3.6
Milo	11.5	2.0	10.5	2.5	70.5	3.0
Oats	10.0	3.5	11.0	11.0	60.0	4.5
Oat meal or groats	8.3	2.2	15.0	2.0	66.0	6.5
Oat mill feed	7.0	5.7	.6.0	27.7	51.5	2.1
Peanuts (hulls on)	6.0	2.8	24.8	17.8	14.0	34.6
Peanut kernels	5.4	2.3	30.4	2.7	11.6	47.6
Peanut meal (43%)	9.0	5.5	43.0	11.5	23.5	7.5
Peanut meal (41%)	8.8	5.7	41.0	12.5	24.0	8.0
Rice, rough	10.5	5.0	8.0	9.0	65.5	2.0
Rice, polished	11.8	.5	7.5	0.4	79.4	0.4

Table 8—(Continued)

Feedstuff	Moisture	Ash	Crude protein	Carbohydrates		Fat, or ether extract
				Crude fiber	Nitrogen-free extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Grains and seeds, and their byproducts						
Rice bran	8.8	10.9	13.0	12.5	41.1	13.7
Rice polishings	9.5	7.0	12.5	3.5	56.5	11.0
Rye	10.7	2.0	11.5	2.1	72.0	1.7
Sesame seed meal	8.5	10.0	41.0	6.0	22.5	12.0
Shallu	10.0	1.8	12.9	1.8	70.0	3.5
Soybeans	8.8	4.8	37.9	5.0	26.6	16.9
Soybean meal (43%)	10.0	5.6	43.0	5.2	30.2	6.0
Soybean meal (41%)	9.0	6.5	41.0	7.0	31.5	5.0
Soybean meal, solvent extracted (45%)	11.5	5.8	45.0	5.5	31.0	1.2
Sunflower seed	7.4	3.4	16.0	28.6	21.4	23.2
Sunflower seeds (hulled)	5.0	3.8	28.0	6.0	16.2	41.0
Sunflower seed, Hungarian striped	6.7	3.7	18.0	25.9	19.3	26.4
Sunflower seed meal (with hulls)	10.5	5.5	21.0	34.0	27.5	1.5
Sunflower seed meal (hulled)	10.0	6.2	36.0	14.0	20.3	13.5
Velvet beans	10.0	3.0	24.8	6.2	50.8	5.2
Wheat	12.0	1.7	12.0	2.4	70.0	1.9
Wheat bran	10.2	5.9	15.6	9.0	55.1	4.2
Wheat flour	12.9	.4	10.7	.4	74.2	1.4
Wheat flour middlings	10.5	3.5	17.0	5.1	59.3	4.6
Wheat germ meal	10.5	4.5	28.5	2.5	44.5	9.5
Wheat middlings, standard	11.0	4.5	16.0	7.5	56.5	4.5

Wheat red dog flour	10.2	2.7	16.9	6.6	56.6	4.7
Wheat shorts (brown)	10.5	4.0	17.5	7.5	56.0	4.5
Wheat shorts (gray)	10.5	4.1	17.7	5.6	57.5	4.6
Wheat shorts (white)	10.5	2.0	16.0	3.0	65.3	3.2
Products of animal origin						
Beef scrap	6.5	21.5	58.0	2.2	0.7	11.1
Blood meal	13.2	3.5	80.0	.7	1.8	.8
Bone meal, steamed	3.1	73.8	13.0	.8	2.8	6.5
Bone meal, special steamed	3.1	85.1	6.5	2.6	2.1	.6
Buttermilk, liquid	90.8	.8	3.2	.0	4.6	.6
Buttermilk, condensed	71.6	3.5	10.6	.0	12.2	2.1
Buttermilk, dried	8.0	10.0	32.5	.2	44.0	5.3
Casein	7.1	3.0	85.0	.1	4.0	.8
Crab meal	8.0	39.0	36.0	8.0	6.5	2.5
Eggs (contents), liquid	73.1	1.0	13.3	0.0	1.1	11.5
Eggs (contents), dried	5.0	3.5	47.0	0.0	3.9	40.6
Fish meal, unidentified	10.0	20.0	60.0	.7	2.5	6.8
Fish meal, herring	9.1	15.0	65.0	.2	1.0	9.7
Fish meal, menhaden	8.0	20.5	57.5	1.0	4.0	9.0
Fish meal, white (high ash)	7.8	26.0	61.6	.4	1.2	3.0
Fish meal, white (low ash)	12.1	17.6	60.9	.6	.1	8.7
Fish meal, sardine	8.0	15.5	65.0	.5	4.5	6.5
Fish meal, tuna	7.5	20.0	59.5	.5	4.5	8.0
Fish solubles, condensed	50.0	12.0	33.5	.0	.5	4.0
Gelatin	2.9	2.0	95.0	.0	.0	0.1
Liver meal	5.0	5.1	65.0	.8	9.9	14.2
Liver-and-gland meal	7.5	6.0	65.0	1.5	4.5	15.5
Meat scrap (55%)	7.5	24.0	55.0	2.5	1.0	10.0
Meat-and-bone scrap (50%)	7.5	29.0	50.0	2.5	1.5	9.5
Meat-and-bone scrap (45%)	7.5	32.5	45.0	2.5	2.0	10.5
Milk, whole, liquid	87.0	.7	3.5	.0	4.9	3.9

Table 8—(Continued)

Feedstuff	Moisture	Ash	Crude protein	Carbohydrates		Fat, or ether extract
				Crude fiber	Nitrogen-free extract	
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Products of animal origin						
Pork liver, dried	5.0	5.5	63.5	.5	15.0	10.5
Prok cracklings	5.0	2.5	56.5	.0	4.0	32.0
Shrimp meal (or bran)	11.0	34.0	42.0	9.5	1.5	2.0
Skim milk, liquid	90.5	.7	3.5	.0	5.1	.2
Skim milk, dried	6.6	8.0	34.0	.0	50.5	.9
Tankage (60%)	8.0	19.5	60.0	2.7	1.8	8.0
Whey, liquid	93.7	.6	.8	.0	4.9	.0
Whey, dried	6.3	8.5	12.5	.3	71.7	.7
Green feeds, etc.						
Alfalfa, fresh, green	73.8	2.5	4.6	7.5	10.7	.9
Alfalfa meal (20%)	8.2	12.2	20.0	17.0	40.0	2.6
Alfalfa meal (17%)	8.3	8.8	17.0	26.0	37.4	2.5
Alfalfa meal (13%)	9.0	7.5	13.0	34.0	35.0	1.5
Apple pomace, dried	10.7	3.5	4.5	15.5	61.0	4.8
Beet molasses, liquid	21.5	10.5	6.5	.0	61.5	.0
Beet pulp, dried	10.5	4.9	8.5	18.5	57.0	.6
Cabbage	90.8	.8	1.8	1.1	5.2	.3
Cane molasses, liquid	25.0	7.0	3.0	.0	65.0	.0
Cane mollasses, dried	5.0	10.0	5.0	.1	79.4	.5
Cereal grass, dehydrated	12.0	11.0	23.0	13.5	35.0	5.5

Carrots	20.0	2.5	.3	.0	77.2	.0
Corn molasses	88.4	1.1	1.1	1.2	7.9	.3
Distillers' solubles (corn), dried	5.0	8.5	25.0	2.0	53.5	6.0
Distillers' solubles, dried	5.0	8.5	27.0	2.0	52.5	5.0
Grapefruit residue, dried	9.3	4.3	4.8	11.6	68.7	1.3
Kale	88.4	1.9	2.4	1.5	5.3	.5
Mangels	90.1	1.1	1.5	.8	6.4	.1
Orange peel, dried	14.0	4.1	5.8	10.6	64.8	.7
Orange pulp meal	10.8	3.4	7.5	8.9	67.9	1.5
Potatoes	78.8	.9	2.0	.5	17.7	.1
Rape	84.6	2.2	2.6	2.4	7.6	.6
Red-clover hay	12.3	6.7	12.7	25.7	39.6	3.0
Rutabagas	88.8	1.0	1.2	1.5	7.3	.2
Sweet potatoes	72.0	1.0	1.5	1.3	23.7	.5
Turnips	90.6	.8	1.3	1.1	6.0	.2
Yeast, brewers', dried	7.0	7.5	45.0	1.4	36.1	3.0

Table 9.—The average calcium, phosphorus, and manganese content of some feedstuffs used in the feeding of poultry.

Feedstuff	Calcium (Ca)	Phosphorus (P)	Manganese (Mn)
	Per cent	Per cent	Parts per million
Grains and seeds, and their byproducts			
Acorns of the willow oak	0.26	0.07	?
Babassu meal	.30	.67	?
Barley	.07	.36	16
Beans, navy	.16	.45	13
Bread	.03	.10	4
Brewers' grains, dried	.20	.46	20
Buckwheat	.06	.35	80
Coconut meal, old process	.28	.61	85
Corn or ground corn	.01	.27	5
Corn, Argentine	.02	.30	12
Corn-and-cob meal	.01	.22	?
Corn bran	.03	.25	?
Corn feed meal	.03	.36	?
Corn germ meal	.04	.58	?
Corn gluten feed	.12	.66	24
Corn gluten meal	.07	.37	4
Corn oil-cake meal	.06	.57	?
Cottonseed meal (43%)	.24	1.15	18
Cottonseed meal (41%)	.26	1.18	18
Cowpeas	.10	.46	30
Distillers' dark grains (corn) dried	.19	.85	60
Feterita	.02	.32	?
Field peas	.08	.40	30
Flax seed	.25	.66	35
Garden peas	.08	.40	25
Hegari	.03	.31	?
Hempseed	.22	.87	10
Hominy	.01	.08	2
Hominy feed	.03	.51	16
Kafir	.03	.35	16
Linseed meal	.33	.74	40
Malt sprouts, dried	.22	.70	35
Millet (proso)	.01	.33	35
Milo	.04	.32	15
Oats	.10	.36	34
Oat meal or groats	.08	.44	25
Oat mill feed	.24	.20	?
Peanut kernels	.07	.39	16
Peanut meal (43)	.18	.56	18
Peanut meal (41)	.16	.52	?
Rice, rough	.07	.21	?
Rice, polished	.01	.09	12

Table 9—(Continued)

Feedstuff	Calcium (Ca)	Phosphorus (P)	Manganese (Mn)
Grains and seeds, and their byproducts	Per cent	Per cent	Parts per million
Rice bran	.10	1.84	280
Rice polishings	.04	1.10	?
Rye	.05	.36	35
Sesame seed meal	2.00	1.60	?
Soybeans	.21	.60	31
Soybean meal (43%)	.29	.70	30
Soybean meal (41%)	.28	.66	**
Sunflower seed	.41	.85	?
Sunflower seed meal (hulled)	.43	1.00	?
Wheat	.04	.39	39
Wheat bran	.11	1.21	119
Wheat flour	.02	.11	4
Wheat flour middlings	.08	.73	113
Wheat germ meal	.07	1.01	160
Wheat middlings, standard	.08	.93	119
Wheat red dog flour	.07	.59	35
Wheat shorts	.08	.93	60
Products of animal origin			
Beef scrap	7.23	3.73	5
Blood meal	.34	.25	?
Buttermilk, liquid	.18	.10	0.06
Buttermilk, condensed	.56	.33	0.2
Buttermilk, dried	1.56	1.00	0.4
Casein	*	0.75	?
Crab meal	12.75	.75	150
Eggs (contents), liquid	.06	.22	4
Eggs (contents), dried	.19	.78	14
Fish meal, unidentified	5.75	3.20	45
Fish meal, herring	4.00	2.65	?
Fish meal, menhaden	6.25	3.65	?
Fish meal, white (high ash)	9.09	4.70	?
Fish meal, white (low ash)	5.84	3.04	40
Fish meal, sardine	4.70	2.70	40
Fish meal, tuna	6.25	3.46	?
Fish solubles, condensed	.08	.80	4
Liver meal	.11	.90	4
Liver-and-gland meal	.35	.90	5
Meat scrap (55%)	8.15	4.00	18
Meat-and-bone scrap (50%)	9.85	4.70	12
Meat-and-bone scrap (45%)	11.00	5.11	10
Milk, whole, liquid	.12	.09	0.06

*Highly variable.
**Use next preceding value as an estimate of the quantity.

Table 9—(Continued)

Feedstuff	Calcium (Ca)	Phosphorus (P)	Manganese (Mn)
	Per cent	Per cent	Parts per million
Products of animal origin			
Pork liver, dried	.06	1.12	4
Skim milk, liquid	.13	.11	0.06
Skim milk, dried	1.29	.98	0.6
Tankage (60%)	7.16	3.53	14
Whey, liquid	.05	.04	0.1
Whey, dried	.85	.70	1
Green feed, etc.			
Alfalfa, fresh, green	.42	.07	7
Alfalfa meal (20%)	1.90	.22	30
Alfalfa meal (17%)	1.40	.21	26
Alfalfa meal (13%)	1.20	.20	?
Apple pomace	.10	.10	?
Beet molasses	.04	02	?
Cabbage	.07	.04	2
Cane molasses, liquid	.56	.03	?
Cane molasses, dried	1.12	.08	?
Carrots	.05	.05	3
Distillers' solubles, dried	.35	1.55	75
Grapefruit residue, dried	.74	.10	3
Kale	.18	.07	6
Mangels	.02	.04	?
Orange peel, dried	.73	.11	8
Orange pulp meal	.64	.10	?
Potatoes	02	.06	2
Rape	.34	.07	50
Red clover hay	1.17	.18	40
Rutabagas	.06	.04	16
Sweet potatoes	.04	.06	4
Turnips	.05	.05	1
Yeast, brewers', dried	1.30	1.25	2
Calcium, phosphorus, and manganese supplements			
Bone, fresh	22.95	10.42	12
Bone meal	27.00	13.00	13
Bone meal, steamed	28.80	13.34	5
Bone meal, special steamed	31.30	14.49	2
Calcite, high calcium	39.00	0.00	200

Table 9—(Continued)

Feedstuff	Calcium (Ca)	Phosphorus (P)	Manganese (Mn)
Calcium, phosphorus, and manganese supplements	Per cent	Per cent	Parts per million
Calcite	35.00	Trace	300
Crabshell	23.75	2.55	300
Defluorinated phosphate (rock), high phosphorus	28.00	13.50	?
Defluorinated phosphate (rock), low phosphorus	21.00	8.50	?
Defluorinated superphosphate	26.50	12.30	?
Di-calcium phosphate	27.00	20.00	?
Gypsum	25 00	Trace	?
Limestone, high calcium	39.00	0 00	100
Limestone	35.00	Trace	200
Oystershell, washed	38.00	Trace	100
			Per cent
Manganese sulphate, anhydrous, C. P.	.00	.00	36.3
Manganese sulphate, tetrahydrate, C. P.	00	.00	24 6
Manganese sulphate, feeding grade (65% $MnSO_4$)	Trace	Trace	23.7

Table 10. The average magnesium, potassium, and sodium content and minimum salt equivalent of some feedstuffs used in the feeding of poultry

Feedstuff	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Minimum salt equivalent (NaCl)
	Per cent	Per cent	Per cent	Per cent
Grains and seeds, and their byproducts				
Barley	0.14	0.48	0.07	0.17
Beans, navy	.15	1.14	.08	.10
Bread	.03	.11	.45	1.00
Brewers' grains, dried	.15	.13	.26	.10
Buckwheat	.09	.42	.05	.07
Coconut meal, old process	.18	1.66	.11	.27
Corn or ground corn	.12	.34	.03	.08
Corn bran	.08	.37	.00	.00
Corn gluten feed	.30	.67	.81	.25
Cottonseed meal	.55	1.56	.25	.05
Cowpeas	.20	1.40	.16	.07
Distillers' dark grains (corn), dried	.30	.80	.18	.28
Garden peas, dried	.13	.95	.08	.11
Hominy	.04	.22	.04	.08
Kafir	.13	.25	.05	.13
Linseed meal	.55	1.25	.14	.35
Malt sprouts, dried	.15	1.50	1.30	.58
Oats	.16	.45	.16	.13
Oat meal, or groats	.13	.39	.05	.08
Peanut kernels	.16	.61	.04	.07

Peanut meal	.22	1.20	.07	.05
Rice, rough	.12	.34	.07	.04
Rice, polished	.03	.07	.03	.04
Rye	.14	.50	.05	.05
Sesame seed meal	.77	1.20	.26	.10
Soybeans	.23	1.80	.35	.05
Soybean meal	.28	2.00	.45	.06
Wheat	.15	.50	.05	.13
Wheat bran	.53	1.25	.13	.12
Wheat flour	.02	.10	.07	.12
Wheat germ meal	.34	.30	.72	.12
Wheat middlings, standard	.37	1.10	.14	.05
Wheat red dog flour	.29	.49	.50	.23
Products of animal origin				
Blood meal	.03	.23	.87	1.50
Bone meal, special steamed	.85	.15	.20	?
Buttermilk, dried	.14	1.70	.50	1.30
Eggs (contents), liquid	.01	.14	.12	.20
Fish meal, unidentified	.20	.59	1.05	1.50
Fish meal, herring	.19	.45	.67	.71
Fish meal, white	.20	.29	1.45	2.45
Fish meal, sardine	.25	.62	.59	.62
Fish solubles, condensed	.02	1.90	1.85	4.60
Milk, whole, liquid	.01	.14	.05	.17
Meat scrap (55%)	.17	.55	1.50	3.50
Skim milk, dried	.15	1.50	.54	1.65
Tankage (60%)	.15	.55	1.50	3.75
Whey, dried	.12	2.50	.48	1.20

Table 10—(Continued)

Feedstuff	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Minimum salt equivalent (NaCl)
	Per cent	Per cent	Per cent	Per cent
Green feeds, etc.				
Alfalfa, fresh, green	07	50	06	11
Alfalfa meal (17%)	27	2 00	20	50
Cabbage	01	29	03	06
Cane molasses	33	2 60	?	?
Carrots	02	31	07	06
Distillers' solubles, dried	80	1 80	30	49
Kale	04	39	05	13
Potatoes	02	50	02	06
Red-clover hay	30	2 00	?	?
Rutabagas	01	20	02	05
Sweet potatoes	02	37	03	07
Turnips	02	33	07	08
Yeast, brewers', dried	90	1 50	09	?

Table 11.—The average iron, idone, and copper content of some feedstuffs used in the feeding of poultry.*

Feedstuff	Iron (Fe)	Iodine (I)	Copper (Cu)
Grain and seeds, and their byproducts	Parts per million	Parts per million	Parts per million
Barley	50	0.05	7.5
Beans, navy	85	.05	9.5
Bread	9	?	2.0
Buckwheat	?	.08	?
Coconut meal	40	?	?
Corn or ground corn	35	.05	4.5
Cottonseed meal	600	.12	?
Cowpeas	10	?	?
Distillers' dark grains	300	?	70.0
Garden peas, dried	55	?	8.0
Hominy	9	?	?
Linseed meal	?	.07	?
Millet	?	.01	?
Milo	?	.02	?
Oats	70	.06	8.0
Oatmeal or groats	45	.05	7.0
Peanut kernels	20	?	?
Rice, rough	20	?	?
Rice, polished	8	?	1.5
Rye	45	.05	6.5
Soybeans	25	.09	?
Soybeans meal	30	.13	?
Wheat	50	.04	7.8
Wheat bran	75	.07	?
Wheat flour	10	?	?
Wheat germ meal	75	?	?
Wheat middlings standard'	100	?	?
Wheats shorts (gray)	?	.11	?
Products of animal origin			
Bone meal, steamed	?	.00	?
Buttermilk, dried	30	.70	?
Casein	?	.30	?
Eggs (contents), liquid	30	.08	2.5
Fish meal, sardine	?	1.05	?
Meat-and-bone scrap (50%)	?	1.30	?
Milk, whole, liquid	2	.04	.3
Skim milk, dried	30	?	3.0
Whey, dried	7	?	?

*The range of the content of these three elements in the feedstuffs listed above is so great that the minimum value often is only 5 to 25 per cent of the average.

Table 11—(Continued)

Feedstuff	Iron (Fe)	Iodine (I)	Copper (Cu)
Green feeds, etc.	Parts per million	Parts per million	Parts per million
Alfalfa, fresh, green	15	0.15	2.5
Alfalfa meal (17%)	60	.55	10.0
Beet molasses, liquid	?	1.60	?
Cabbage	10	.01	1.0
Cane molasses	95	1.60	?
Carrots	6	.01	1.1
Cereal grass, dehydrated	?	.20	?
Corn molasses	15	3.50	?
Distillers' solubles, dried	500	?	80.0
Kale	25	?	3.2
Potatoes	10	.01	1.6
Rutabagas	6	?	?
Sweet potatoes	10	?	1.8
Turnips	6	?	.8
Yeast brewers, dried	50	.01	20.0

*The range of the content of these three elements in the feedstuffs listed above is so great that the minimum value often is only 5 to 25 per cent of the average.

Note: Potassium iodide, C.P., contains 76.45 per cent, or 764,500 parts per million, of iodine.

Stabilized potassium iodide (90% KI) contains 68.8 per cent, or 688,000 parts per million, of iodine.

Table 12a.—The average vitamin content of some feedstuffs used in the feeding of poultry: Vitamin A, vitamin D, and vitamin E.

Feedstuff	Vitamin A per pound	Vitamin D per pound	Vitamin E per pound
	I. U.	A. O. A. C. cu.	Mg
Grains and seeds, and their byproducts			
Acorns of the willow oak	80,000	—	?
Barley	320	Trace	20
Bread	40	?	?
Brewers' grains, dried	400	—	20
Corn, white	Trace	—	11
Corn, yellow, average	2,270	—	14
Corn, yellow, new	3,500	—	**
Corn, one year old	2,500	—	**
Corn, two years old	1,800	—	**
Corn, three years old	1,300	—	**
Corn, gluten feed (yellow)	1,000	—	18
Corn, gluten meal (yellow)	12,000	—	10
Cottonseed meal	150	—	12
Cowpeas	220	—	?
Distillers' dark grains (corn), dried	1,100	—	21
Feterita	230	—	?
Hegari	300	—	?
Hominy feed (yellow)	800	—	15
Kafir	280	—	?
Linseed meal	200	—	12
Malt sprouts	?	—	18
Milo	370	—	12
Oats	250	—	23
Peanut kernels	120	—	?
Peanut meal	150	—	?

**Use next preceding value as an estimate of the quantity.

Table 12a—(Continued)

Grains and seeds, and their byproducts	Vitamin A per pound	Vitamin D per pound	Vitamin E per pound
	I. U.	A. O. A. C. cu.	Mg
Products of animal origin			
Rye	70	—	?
Soybeans	400	—	17
Soybean meal	170	Trace	10
Wheat, average	125	—	17
Wheat, new	200	—	**
Wheat bran	175	—	1
Wheat flour middlings	160	—	?
Wheat germ meal	190	—	72
Wheat germ oil	?	—	860
Wheat middlings, standard	225	—	10
Wheat red dog flour	100	—	26
Wheat shorts (gray)	175	—	14
Products of animal origin			
Buttermilk, liquid	25	Trace	—
Buttermilk, dried	200	5	—
Cod-liver oil (850 A — 85 D)	385,500	38,550	—
D-activated animal sterol (2,000 D)	—	900,000	—
Eggs (contents), liquid	6,000	56	Trace
Fish solubles, condensed	1,800	900	—
Liver, pork, dried	45,000	200	?
Milk, whole, liquid	1,080	?	—
Sardine oil	52,000	38,550	—
Skim milk, liquid	15	—	—
Skim milk, dried	130	—	—
Vitamin-A-and-D feeding oil			
(4,000 A—800 D)	1,814,000	362,800	—
(4,000 A—400 D)	1,814,000	181,400	—
(3,000 A—800 D)	1,360,000	362,800	—
(3,000 A—400 D)	1,360,000	181,400	—

Vitiamn A and O feeding oil			
(2,500 A—400 D)	1,134,000	181,400	—
(2,000 A—400 D)	907,000	181,400	—
(1,500 A—400 D)	680,000	181,400	—
(1,000 A—400 D)	454,000	181,400	—
Green feeds, etc.			
Alfalfa, fresh, green	56,000	?	69
Alfalfa hay, dehydrated	91,000	150 I. U.*	?
Alfalfa hay, suncured	19,000	500 I. U.*	12
Alfalfa meal, dehydrated, average	75,000	?	120
Alfalfa meal, dehydrated (20%)	122,000	?	174
Alfalfa meal, dehydrated (17%)	89,000	?	120
Alfalfa meal, dehydrated (13%)	48,000	?	?
Alfalfa meal, sun-cured, average	25,000	750 I. U.*	12
Alfalfa meal, sun-cured, (20%)	50,000	?	20
Alfalfa meal, sun-cured, (17%)	28,000	?	12
Alfalfa meal, sun-cured, (13%)	15,000	?	?
Cabbage	450	—	?
Carrots	18,000	—	?
D-activated animal sterol (2,000 D)	—	900,000	—
D-activated plant sterol (9,000 D)	—	4,000,000 I. U.*	—
Grass oats, young dehydrated	200,000	—	?
Kale	45,000	—	?
Potatoes	220	—	?
Red-clover hay	9,000	?	30
Silage, alfalfa, moist	25,000	?	?
Silage, grass, moist	60,000	?	?
Sweet potatoes	10,000	?	?
Yeast, irradiated (9,000 D)	—	4,000,000 I. U.*	—

*Not well utilized by poultry; should be disregarded in feeds for chickens.

**Use next preceding value as an estimate of the quantity.

Table 12b.—The average vitamin content of some feedstuffs used in the feeding of poultry: Riboflavin, pantothenic acid, choline, niacin, and thiamine.

Feedstuff	Riboflavin per pound	Pantothenic acid per pound	Choline per pound	Niacin per pound	Thiamine per pound
Grains and seeds, and their byproducts	Mg	Mg	Mg	Mg	Mg
Babassu meal	0.58	?	?	?	?
Barley	0.59	3.00	500	31.10	2.50
Beans, mung	?	?	?	10.50	1.80
Beans, navy	1.40	.60	?	13.00	2.40
Beans, pinto	3.60	?	?	?	7.00
Bread	.45	?	?	?	.15
Brewers' grains, dried	.40	1.10	?	?	?
Buckwheat	.25	.65	?	20.00	2.30
Coconut meal	2.30	.40	?	?	?
Corn, white	.55	3.00	200	7.30	2.30
Corn, yellow	.52	2.70	200	7.50	2.10
Corn bran	.75	?	?	?	2.00
Corn feed meal	.54	1.65	?	?	?
Corn germ meal	1.55	6.00	?	13.90	9.90
Corn gluten feed	1.50	4.50	350	47.20	?
Corn gluten meal	1.00	6.00	750	13.60	?
Corn oil-cake meal	3.00	?	?	?	4.50
Cottonseed meal	1.50	5.00	1,180	20.00	5.80
Cowpeas	1.25	8.00	980	10.80	3.90
Distillers' dark grains (corn), dried	3.45	5.00	1,800	38.00	2.00
Distillers' dark grains, dried	3.45	5.30	1,800	37.00	1.80
Durra	0.40	4.45	?	24.00	?
Garden peas	.78	7.00	1,000	?	2.70
Hegari	0.50	3.95	?	30.00	?
Hempseed meal	1.25	3.00	?	?	?

Hominy	.20	?	?	4.00	.35
Hominy feed	.90	?	?	9.00	?
Kafir	.50	2.80	?	18.00	2.30
Linseed meal	1.15	3.60	750	22.00	5.90
Malt sprouts	4.30	?	?	25.00	?
Millet	?	?	?	10.00	3.20
Milo	.50	3.90	?	33.00	?
Oats	.59	4.65	420	6.60	3.45
Oat meal or groats	.50	4.70	560	7.80	2.50
Oat mill feed	1.25	?	?	?	?
Peanut kernels	1.60	20.00	?	58.00	3.70
Peanut meal	2.20	24.00	850	75.00	3.00
Rice, rough	.60	?	?	13.00	1.20
Rice, polished	.20	1.80	350	6.90	.25
Rice bran	1.20	10.00	?	125.00	9.00
Rice polishings	1.00	?	460	300.00	8.90
Rye	.68	4.60	?	6.80	2.00
Sesame seed meal	1.45	2.50	?	?	?
Soybeans	1.20	5.90	850	16.50	5.50
Soybean meal (43%)	1.55	?	?	18.50	4.00
Soybean meal (41%)	1.25	6.20	1,300	18.00	?
Sunflower seed	?	?	?	?	.25
Sunflower seed meal (with hulls)	1.35	19.00	?	113.00	?
Wheat	.55	5.00	330	27.50	2.30
Wheat bran	1.35	11.40	460	139.00	3.50
Wheat flour	.18	?	190	?	.20
Wheat flour middlings	.85	4.60	?	44.00	4.00
Wheat germ meal	2.15	3.90	1,200	23.70	9.00
Wheat middlings, standard	1.15	7.20	500	56.50	5.00
Wheat red dog flour	1.25	6.20	325	21.00	9.00
Wheat shorts (brown)	1.35	6.00	530	43.00	6.00
Wheat shorts (gray)	1.30	5.00	?	?	?
Wheat shorts (white)	?	?	?	40.00	?

Table 12b—(Continued)

Feedstuff	Riboflavin per pound	Pantothenic acid per pound	Choline per pound	Niacin per pound	Thiamine per pound
Products of animal origin	Mg	Mg	Mg	Mg	Mg
Blood meal	.85	.70	?	12.00	?
Buttermilk, liquid	1.25	2.00	?	.60	.20
Buttermilk, dried	13.00	19.50	?	7.80	1.30
Buttermilk, sweet cream, dried	15.00	20.00	?	?	1.40
Casein	2.50	?	90	?	?
Crab meal	2.10	?	800	?	?
Eggs (contents), liquid	1.40	12.20	?	?	.35
Fish meal, average	3.00	3.75	1,380	?	.45
Fish meal, unidentified	3.10	4.00	1,230	?	.45
Fish meal, menhaden	2.20	?	1,500	?	?
Fish meal, sardine	3.00	3.50	1,720	?	.45
Fish meal, white	3.80	?	?	36.00	.45
Fish solubles, condensed	9.00	16.30	1,200	145.00	2.00
Liver meal	20.00	40.00	4,760	80.00	1.00
Meat scrap (55%)	2.60	4.00	1,100	30.00	.55
Meat-and-bone scrap (50%)	2.45	2.00	1,000	25.00	.50
Meat-and-bone scrap (45%)	2.35	1.50	750	22.00	?
Milk, whole, liquid	.85	1.40	390	.75	.20
Pork liver, dried	40.00	80.00	?	450.00	7.00
Shrimp meal	1.00	?	?	?	?
Skim milk, liquid	.90	1.70	?	.50	.20
Skim milk, dried	8.50	15.00	490	7.00	1.55
Tankage (60%)	.80	1.00	990	30.00	.45
Whey, liquid	.75	2.40	?	.40	?
Whey, dried	10.90	21.00	700	8.50	1.00

Green feeds, etc.					
Alfalfa, fresh, green	2.20	5.00	?	8.20	.70
Alfalfa meal, dehydrated (20%)	8.40	17.00	?	24.00	3.00
Alfalfa meal, dehydrated (17%)	6.70	16.00	500	22.00	2.00
Alfalfa meal, dehydrated (13%)	6.00	?	?	18.00	?
Alfalfa meal, sun-cured (20%)	7.30	12.00	?	22.00	1.60
Alfalfa meal, sun-cured (17%)	5.00	10.00	?	21.00	1.30
Alfalfa meal, sun-cured (13%)	4.20	?	?	17.00	?
Apple pomace, dried	.50	?	?	?	?
Beet pulp, dried	.65	?	?	11.50	?
Cabbage	.25	?	860	1.30	.33
Cane molasses, liquid	1 00	15.00*	290	21.00	.45
Carrots	.30	1.00	325	6.70	.30
Cereal grass, dried	7.00	?	?	33.50	?
Corn molasses	.25	?	?	?	?
Distillers' solubles (corn), dried	7.50	10.40	2,750	70.00	4.00
Distillers' solubles, dried	7.00	11.00	?	68.00	3.20
Kale	2.25	2.00	?	?	.75
Potatoes	.15	1 50	360	5.00	.65
Red-clover hay	8.00	?	?	16.60	1.25
Sweet potatoes	0 25	5.00	130	6.00	0.45
Turnips	.20	1.50	320	?	.35
Yeast, brewers' dried	16.00	50.00**	1,500	200.00	25.00

*Highly variable, ranging from 5 to 30 mg per lb.
**Very highly variable, ranging from 10 to 150 mg per lb.

Note:
1 pound of riboflavin = 453,590 mg of riboflavin
1 pound of calcium (d,1) pantothenate = 220,500 mg of pantothenic acid
1 pound of calcium (d) pantothenate = 417,390 mg of pantothenic acid
1 pound of choline chloride = 393,650 mg of choline
1 pound of niacin = 453,590 mg of niacin
1 pound of thiamine = 453,590 mg of thiamine

Table 13a.—The average amino acid content of some feedstuffs used in the feeding of poultry: Arginine, lysine, methionine, cystine, tryptophane, and glycine.

Feedstuff	Protein (N x 6.25)	Arginine	Lysine	Methionine	Cystine	Tryptophane	Glycine
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Grains and seeds, and their byproducts							
Barley	11.0	0.46	0.21	0.22	0.20	0.13	?
Corn	9.0	.36	.22	.21	.12	.06	0.38
Corn germ meal	20.0	1.5	1.2	.31	.32	.26	?
Corn gluten feed	25.0	.61	.68	.25	?	.14	?
Corn gluten meal	41.0	1.3	.68	.99	.58	.24	1.7
Cottonseed meal	41.0	3.1	1.2	.72	.84	.47	2.2
Distillers' dark grains (corn), dried	28.0	.77	.60	.43	?	.10	?
Distillers' dark grains, dried	28.0	.89	.71	.45	?	.17	?
Flaxseed	22.0	1.5	.44	.51	.42	.37	?
Garden peas, dried	25.6	2.3	1.3	.20	.31	.18	?
Linseed meal	34.0	2.5	.94	.68	.65	.54	?
Milo	10.5	.36	.27	.16	?	.11	?
Oats	11.0	.55	.37	.24	.18	.11	?
Oatmeal or rolled oats	15.0	.89	.50	.29	.26	.20	?
Peanut, meal	41.0	4.1	1.2	.49	.66	.39	2.3
Rice, polished	7.5	.54	.24	.24	.11	.10	.77
Rye	11.5	.49	.46	.13	?	.13	?
Sesame seed meal	41.0	3.7	1.2	1.3	.53	.70	3.8
Soybean meal	41.0	2.5	2.4	.70	.72	.51	6.6
Sunflower seed meal	21.0	1.7	.87	.76	.32	.27	.84
Wheat	12.0	.43	.32	.23	.20	.14	.87

Wheat bran	15.6	.90	.51	.28	.22	.23	?
Wheat flour	10.7	.36	.22	.11	.20	.09	.77
Wheat germ meal	28.5	1.7	1.6	.50	.21	.29	?
Wheat middlings, standard	16.0	.77	.43	.27	.18	.18	.45
Wheat red dog flour	16.9	.64	.50	.25	?	.14	?
Products of animal origin							
Blood meal	80.0	3.3	6.9	1.0	1.5	1.0	?
Buttermilk, dried	32.5	1.0	2.2	.66	?	.42	?
Casein	85.0	3.5	6.7	2.7	.28	1.1	1.8
Eggs (contents), liquid	13.3	.86	.80	.64	.33	.20	.32
Fish meal (unidentified)	60.0	3.8	4.0	1.8	.63	.69	3.3
Fish meal, sardine	65.0	4.8	4.2	2.2	.75	.81	3.6
Fish solubles, condensed	33.5	1.5	1.5	.49	.20	.20	?
Gelatin	95.0	7.6	4.4	.74	.10	.00	22.4
Liver meal	65.0	3.5	4.1	1.5	.91	.78	?
Meat scrap	55.0	3.7	3.1	1.2	.58	.35	2.5
Milk, whole	3.5	.11	.28	.10	.04	.05	.08
Skim milk, dried	34.0	1.2	2.5	.87	.41	.41	.19
Tankage	60.0	3.6	3.9	.64	?	.45	?
Whey, dried	12.5	.39	.88	.29	.38	.21	.00
Green feeds, etc.							
Alfalfa meal	20.0	.86	.94	.30	.32	.28	?
Alfalfa meal	17.0	.80	.80	.27	.28	.26	?
Carrots	1.1	.007	.013	.006	?	.003	?
Distillers' solubles (corn), dried	25.0	.56	.65	.38	?	.09	?
Distillers' solubles, dried	27.0	.85	.66	.38	?	.09	?
Yeast, brewers', dried	45.0	1.9	3.3	.86	.45	.59	?

Table 13b.—The average amino acid content of some feedstuffs used in the feeding of poultry: Isoleucine, leucine, phenylalanine, threonine, valine, histidine, and tyrosine.

Feedstuff	Protein (N x 6.25)	Isoleucine	Leucine	Phenyl-alanine	Threo-nine	Valine	Histidine	Tryrosine
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Grains and seeds and their byproducts								
Barley	11.0	0.43	0.61	0.44	0.25	0.44	0.18	0.12
Corn	9.0	.41	1.4	.44	.32	.46	.22	.54
Corn germ meal	20.0	.76	2.8	1.1	.92	1.2	.58	1.2
Corn gluten feed	25.0	1.1	2.8	.90	.88	1.3	.63	.38
Corn gluten meal	41.0	2.1	7.7	2.4	1.5	2.1	.76	2.3
Cottenseed meal	41.0	1.6	2.1	2.2	1.2	1.8	1.1	1.2
Distillers' dark grains (corn), dried	28.0	1.7	2.1	1.8	.94	1.5	.69	.60
Distillers' dark grains, dried	28.0	1.7	2.0	1.7	.98	1.6	.43	.53
Flax seed	22.0	.66	1.3	1.3	.88	1.6	.42	.99
Garden peas, dried	25.6	1.0	1.6	1.2	1.0	1.0	.31	?
Linseed meal	34.0	1.4	2.1	1.7	1.6	1.9	.51	1.7
Milo	10.5	.53	1.4	.48	.27	.57	.27	.18
Oats	11.0	.50	.72	.52	.33	.55	.29	.33
Oatmeal or rolled oats	15.0	.83	1.2	1.0	.53	.96	.33	.69
Peanut meal	41.0	1.4	2.4	2.2	.62	2.3	.86	1.8
Rice, polished	7.5	.39	.65	.50	.30	.47	.10	.42
Rye	11.5	.46	.68	.59	.32	.55	.20	.14
Sesame seed meal	41.0	2.0	3.1	3.4	1.5	2.1	.62	1.8
Soybean meal	41.0	2.1	3.0	2.1	1.7	2.0	1.0	1.4
Sunflower seed meal	21.0	1.1	1.3	1.1	.84	1.1	.36	.55
Wheat	12.0	.44	.73	.61	.35	.52	.26	.49
Wheat bran	15.6	.60	.86	.51	.33	.77	.42	.17
Wheat flour	10.7	.42	.78	.57	.27	.42	.21	.35
Wheat germ meal	28.5	.86	2.0	1.2	1.1	1.2	.71	1.1
Wheat middlings, standard	16.0	.76	.90	.69	.41	.83	.41	.20
Wheat red dog flour	16.9	.71	.92	.36	.43	.85	.43	.14
Products of animal origin								
Blood meal	80.0	.92	9.4	5.5	4.4	6.2	4.2	3.0
Buttermilk, dried	32.5	2.3	3.1	1.3	1.4	2.5	.84	.92
Casein	85.0	5.7	8.9	4.6	3.7	6.0	2.7	5.4

Eggs (contents), liquid	13.3	1.1	1.2	.80	.61	.97	.28	.63
Fish meal (unidentified)	60.0	3.2	4.9	2.7	2.6	3.1	1.5	2.0
Fish meal, sardine	65.0	3.6	4.6	2.5	2.9	3.9	1.6	2.9
Fish solubles, condensed	33.5	.50	.77	.62	.70	.87	1.2	.25
Gelatin	95.0	1.8	3.4	2.2	1.7	2.8	.95	.19
Liver meal	65.0	3.1	5.4	3.1	2.5	3.7	1.6	2.3
Meat scrap	55.0	2.3	4.7	2.4	2.1	2.7	1.4	1.7
Milk, whole	3.5	.24	.37	.19	.15	.26	.09	.19
Skim milk, dried	34.0	2.2	3.2	1.6	1.4	2.4	1.1	.77
Tankage	60.0	1.9	5.0	2.7	1.9	3.3	1.6	1.5
Whey, dried	12.5	.78	1.1	.44	.63	.73	.19	.25
Green feed, etc.								
Alfalfa meal	20.0	.87	1.3	.87	.68	1.0	.36	.80
Alfalfa meal	17.0	.74	1.1	.74	.58	.78	.31	.61
Carrots	1.1	.032	.053	.031	.030	.037	.008	?
Distillers' solubles (corn), dried	25.0	1.4	1.3	1.6	.84	1.3	.65	.56
Distillers' solubles, dried	27.0	1.6	1.5	1.6	.95	1.5	.66	.57
Yeast, brewers', dried	45.0	2.6	3.2	2.0	2.3	2.4	1.2	1.3

Table 14.—Average digestibility in the chicken of some feedstuffs used in the feeding of poultry.

Feedstuff	Organic matter	Crude Protein	Crude fiber	Nitrogen-free extract	Fat, or ether extract	Total digestible nutrients
Grains and seeds, and their byproducts	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Barley	76	74	9	82	69	67
Beans, navy	40	42	16	41	64	34
Beans, pinto	40	43	28	39	96	36
Brewers' grains, dried	65	80	12	78	60	63
Broom corn	71	46	13	82	91	65
Buckwheat	73	60	9	85	87	65
Coconut meal	41	56	15	32	92	45
Corn, whole or cracked	87	76	12	90	86	80
Corn, Argentine, whole or cracked	88	84	16	91	81	83
Corn, ground	88	79	6	92	88	81
Corn, Argentine, ground	88	83	13	91	91	84
Corn bran	35	54	7	33	89	36
Corn feed meal	80	85	5	82	82	74
Corn gluten feed	47	62	4	44	65	42
Corn gluten meal	66	81	11	57	55	61
Cottonseed meal	70	74	11	86	90	67
Cowpeas	75	55	12	87	89	65
Feterita	89	88	33	91	81	82
Field peas	74	76	12	80	80	66
Flax seed	76	90	6	60	93	101
Garden peas, dried	83	88	10	86	86	72
Hegari	92	86	42	95	77	83
Hempseed	61	75	?	65	90	83
Kafir	89	82	15	93	80	80
Linseed meal	41	62	9	24	76	41

Millet (proso)	74	76	17	89	82	73
Milo	91	85	26	94	82	81
Mixed feed (laying mash)	85	85	44	88	92	83
Oats	65	73	13	72	82	61
Oat meal or groats	88	82	16	91	89	86
Peanut kernels	77	80	4	84	78	118
Peanut meal	65	75	6	70	80	63
Rice, rough	74	74	5	84	72	65
Rice, polished	95	90	50	96	75	84
Rice bran	55	59	4	60	80	57
Rice polishings	84	79	9	88	93	83
Rye	79	67	13	84	42	70
Shallu	90	78	39	94	85	83
Soybeans	76	74	28	80	90	85
Soybean meal	76	81	3	82	80	70
Soybean meal, solvent extracted	74	80	1	80	38	62
Sunflower seed	44	66	11	16	95	67
Sunflower seed, Hungarian striped	49	84	4	17	94	75
Sunflower seed meal (with hulls)	50	77	3	86	82	44
Wheat	84	79	9	88	50	73
Wheat bran	45	61	8	46	58	41
Wheat flour	94	85	81	95	96	83
Wheat middlings, standard	62	72	7	67	60	56
Wheat shorts (gray)	65	69	10	67	85	60
Products of animal origin						
Beef scrap	89	92	—	—	94	77
Blood meal	87	90	—	—	90	74
Bone meal, steamed	76	90	—	—	90	25
Buttermilk, dried	81	81	—	81	86	72
Casein	80	85	—	?	?	72

Table 14—(Continued)

Feedstuff	Organic matter	Crude Protein	Crude fiber	Nitrogen-free extract	Fat, or ether extract	Total digestible nutrients
Products of animal origin	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Fish meal, unidentified	88	90	—	50	91	69
Gelatin	75	75	—	—	—	71
Liver meal	66	65	—	45	91	76
Meat scrap (55%)	85	90	—	—	90	70
Meat-and-bone scrap (50%)	84	90	—	—	90	64
Meat-and-bone scrap (45%)	83	90	—	—	90	62
Milk, whole, liquid	94	95	—	94	92	16
Shrimp meal (or bran)	53	60	17	55	86	32
Skim milk, liquid	94	93	—	94	92	8
Skim milk, dried	83	81	—	85	85	72
Tankage (60%)	80	85	—	—	90	67
Green feeds, etc						
Alfalfa, fresh green	56	65	44	61	55	14
Alfalfa meal (20%)	44	85	4	40	40	36
Alfalfa meal (17%)	23	65	—	20	25	20
Beet pulp, dried	18	37	4	20	50	16
Cabbage	76	72	71	80	57	7
Carrots	85	68	54	93	64	9
Potatoes	83	63	13	88	41	17
Red clover hay	35	65	10	40	50	30
Rutabagas	84	75	65	90	75	9
Sweet potatoes	82	40	20	88	70	23
Turnips	79	68	35	90	74	7
Yeast, brewers', dried	71	75	5	70	60	63

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(The more important references are given in bold face.)

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